Daytime azimuthal variation of longwave radiance from CERES-SSF

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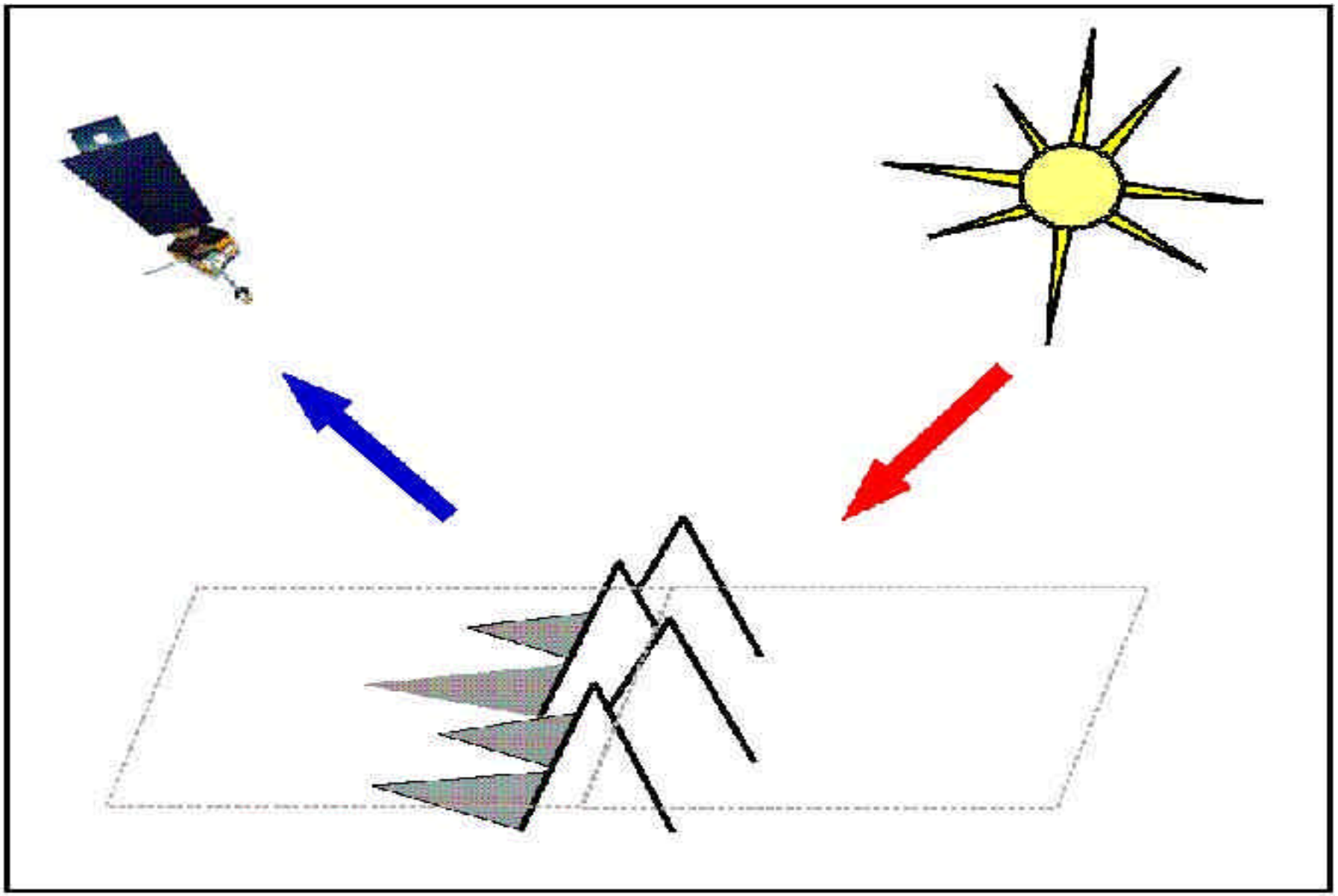
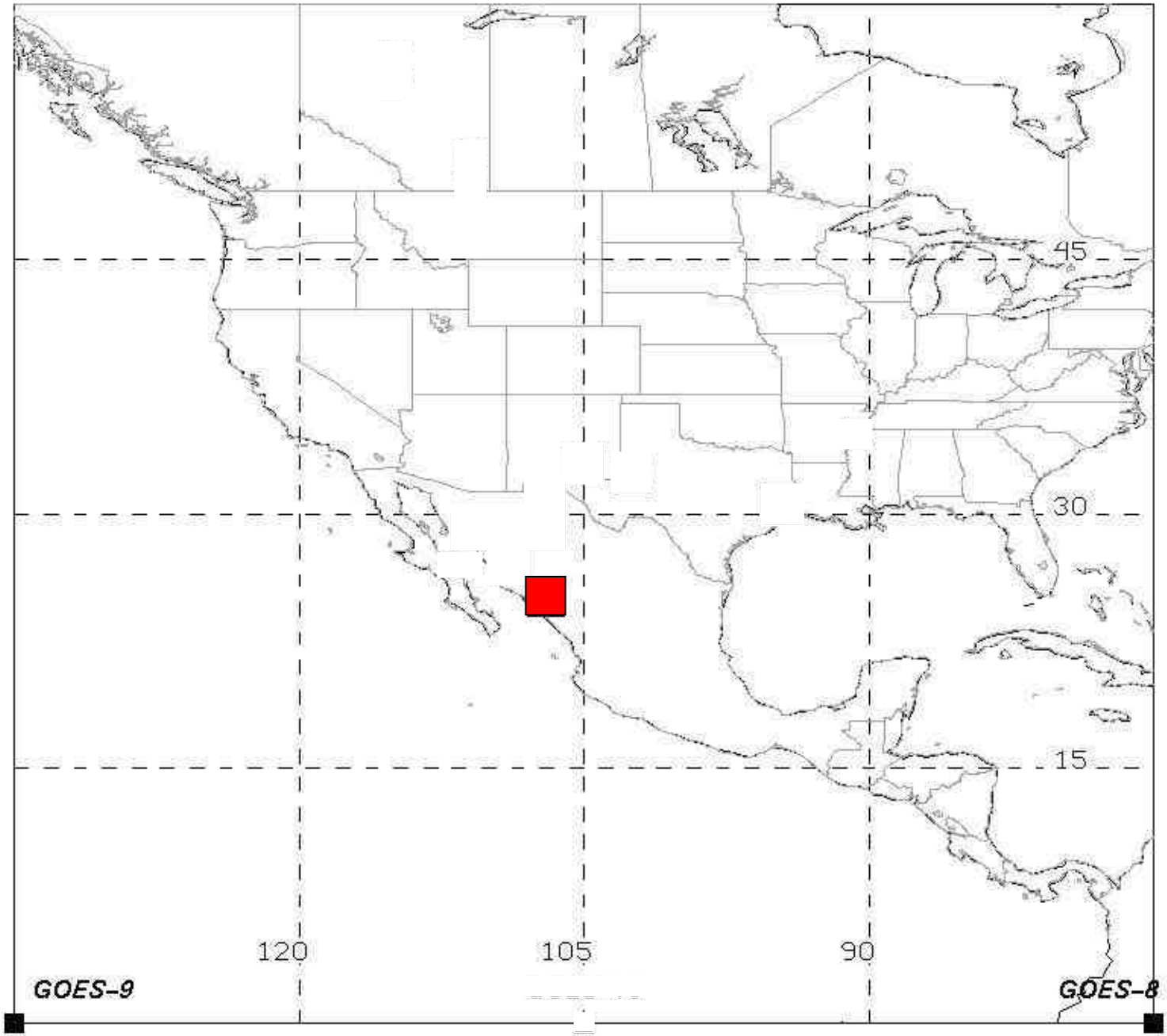
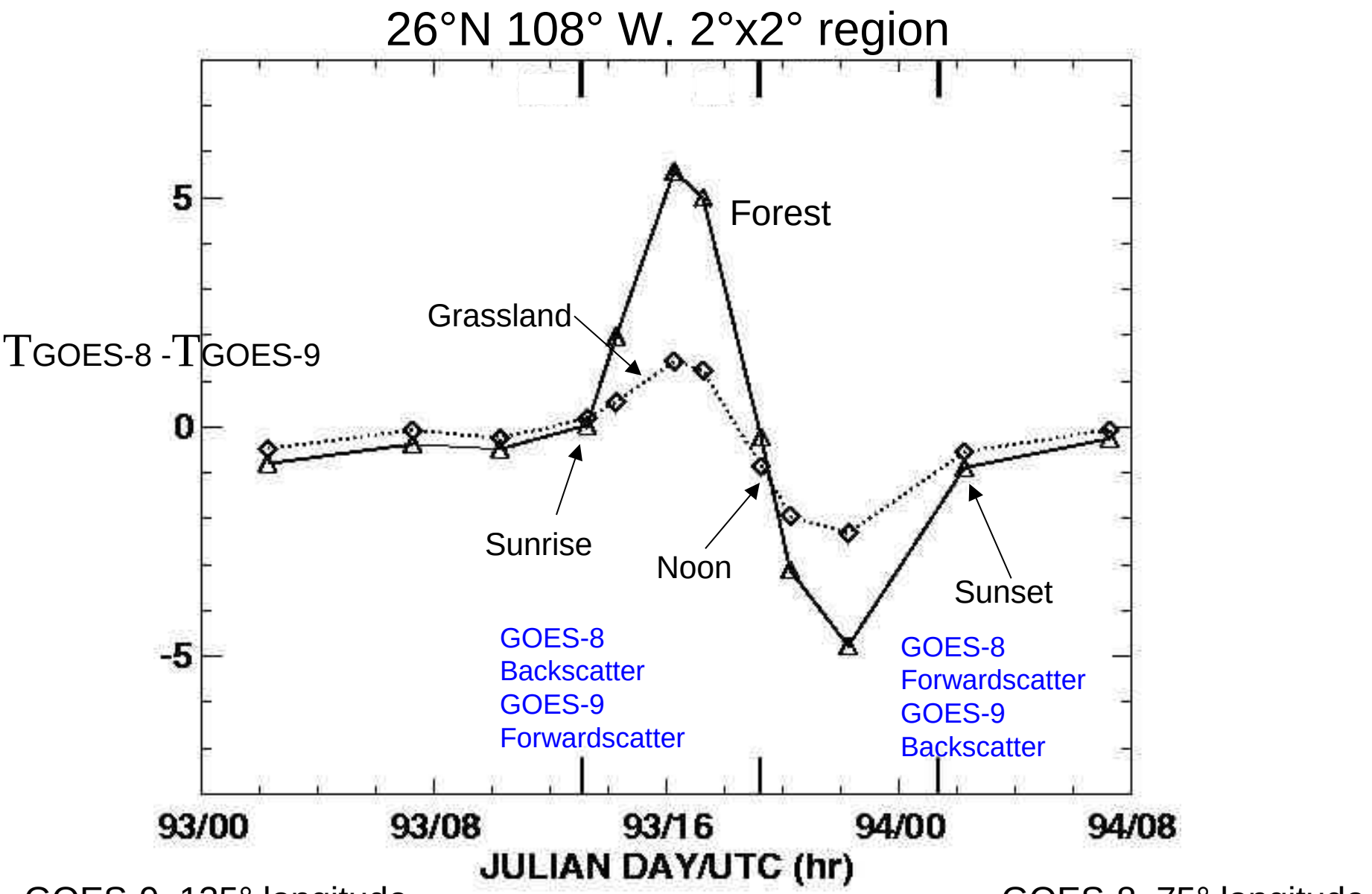


Forward scatter
Colder temperature measured

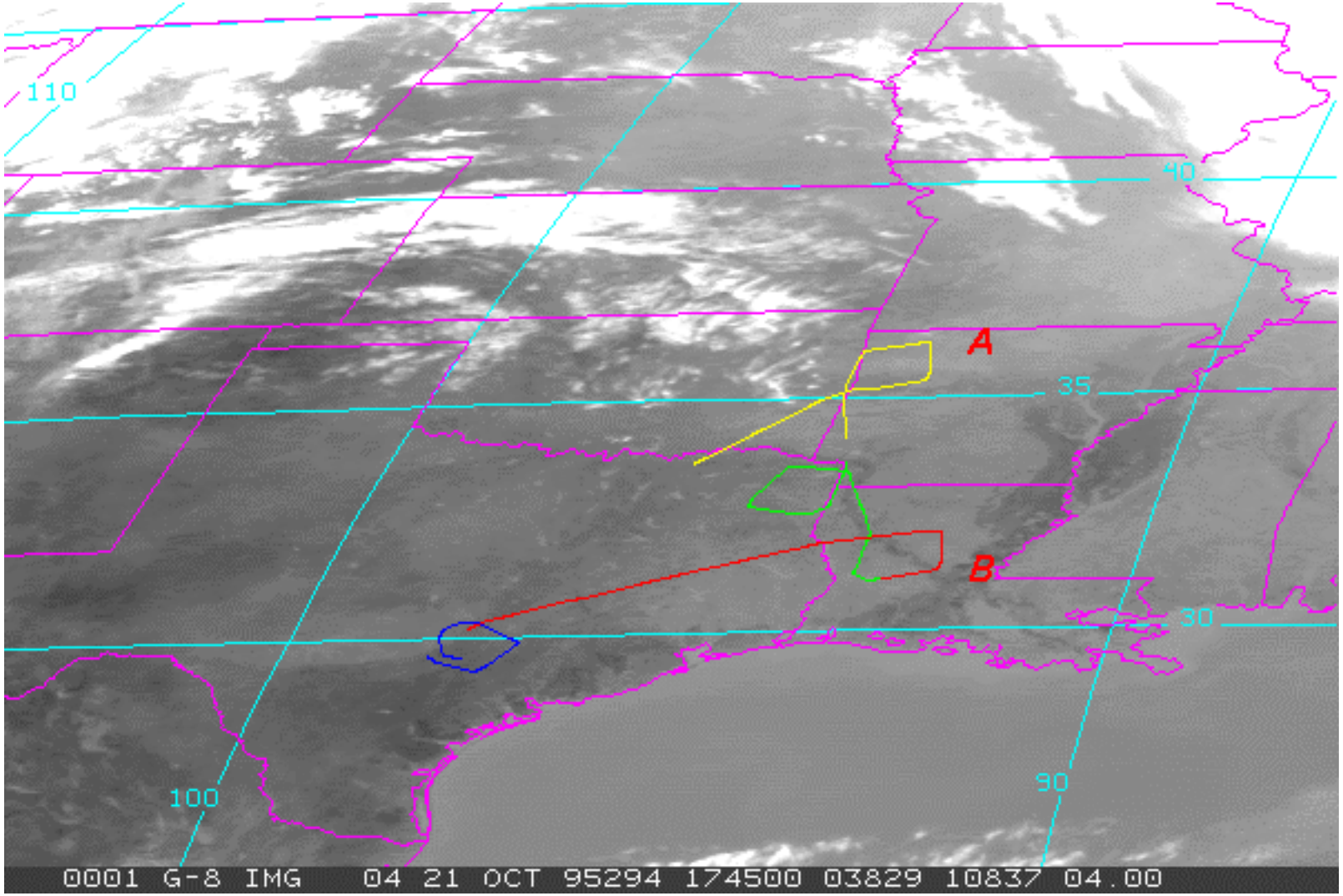
Back scatter
Warmer temperature measured


45
30
15
120
105
90
GOES-9
GOES-8


26°N 108° W. 2°x2° region
5
0
-5
TGOES-8 - TGOES-9
Forest
Grassland
Sunrise
Noon
Sunset
GOES-8
Backscatter
GOES-9
Forwardscatter
GOES-8
Forwardscatter
GOES-9
Backscatter
93/00
93/08
93/16
94/00
94/08
JULIAN DAY/UTC (hr)
GOES-9, 135° longitude
GOES-8, 75° longitude

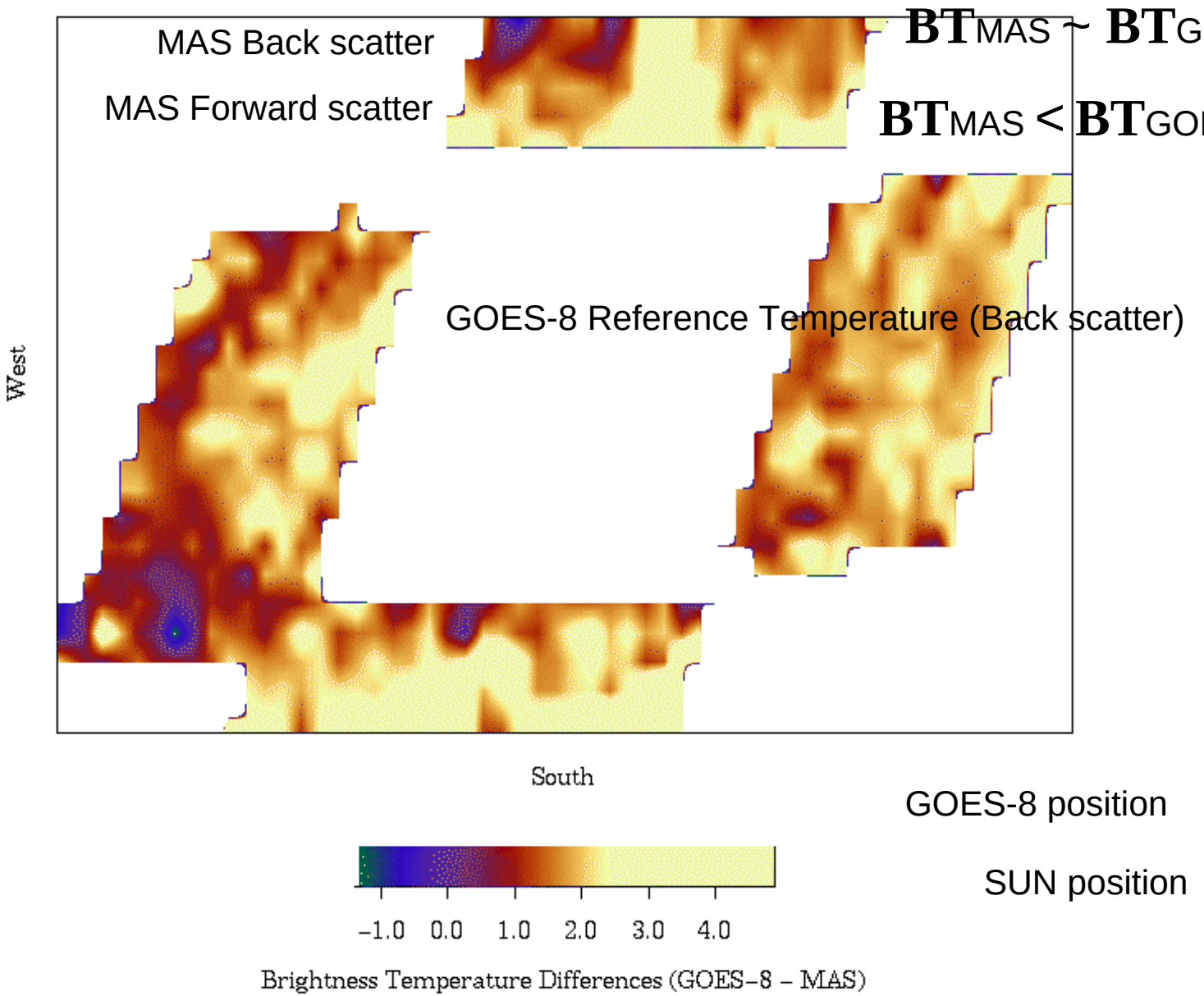
GOES-8 MAS Comparisons

- October 21, 1995, A=Ozarks, B=Louisiana
- MAS pixels (50m) averaged into GOES-8 pixel (4km)
  - 4500 MAS to 1 GOES-8 pixel
  - MAS flight track 8 GOES-8 pixels wide
  - ER-2 (20 km altitude)
- Perform correlated K's to remove MAS limb darkening
- Inter-calibrate GOES-8 and MAS 11um temperatures over the Gulf of Mexico
- Compute brightness temperature difference (GOES-8 -MAS)

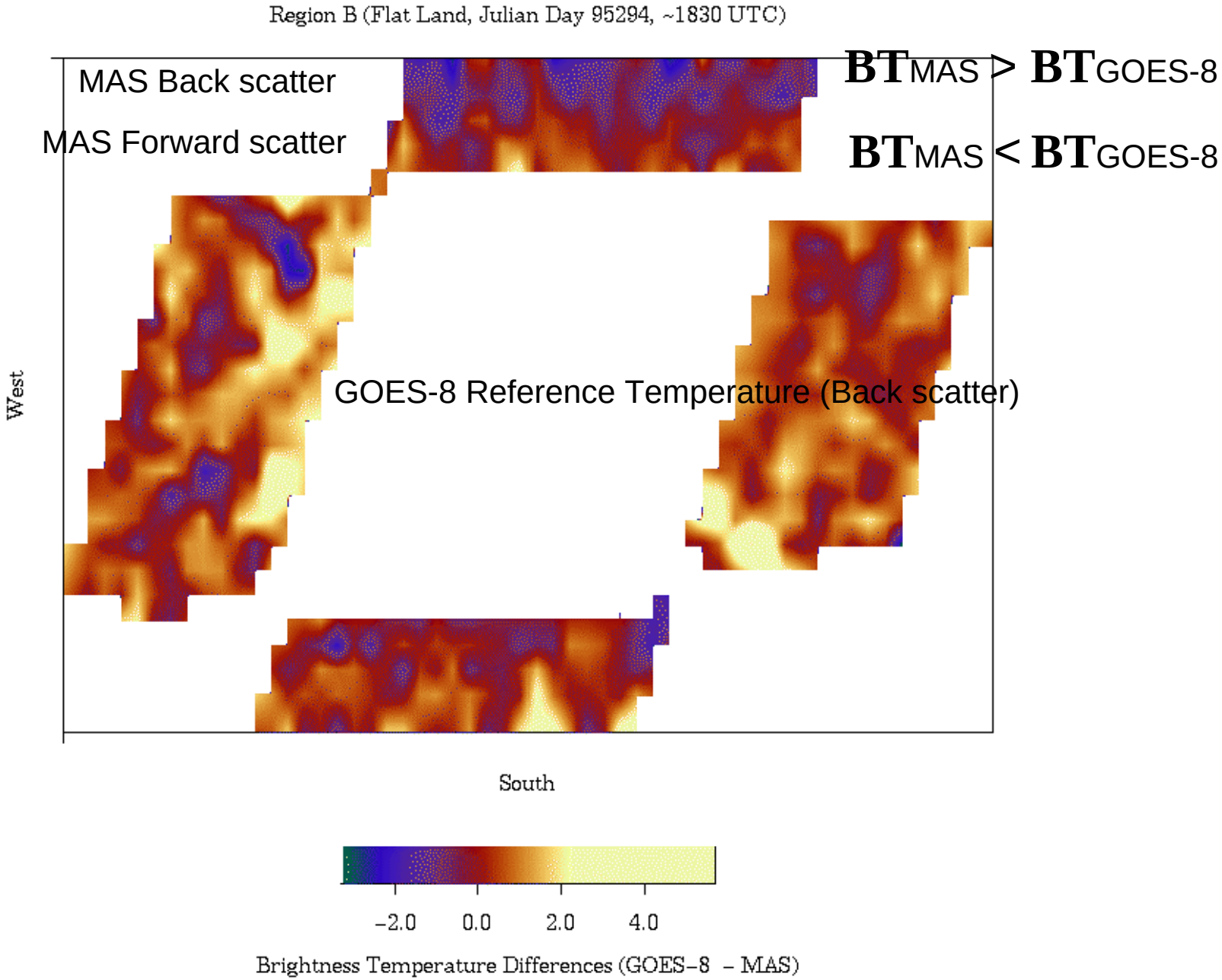

110
40
A
35
B
30
100
90
0001 G-8 IMG 04 21 OCT 95294 174500 03829 10837 04.00

OZARKS

Region A (Rolling Land, Julian Day 95294, ~1665 UTC)

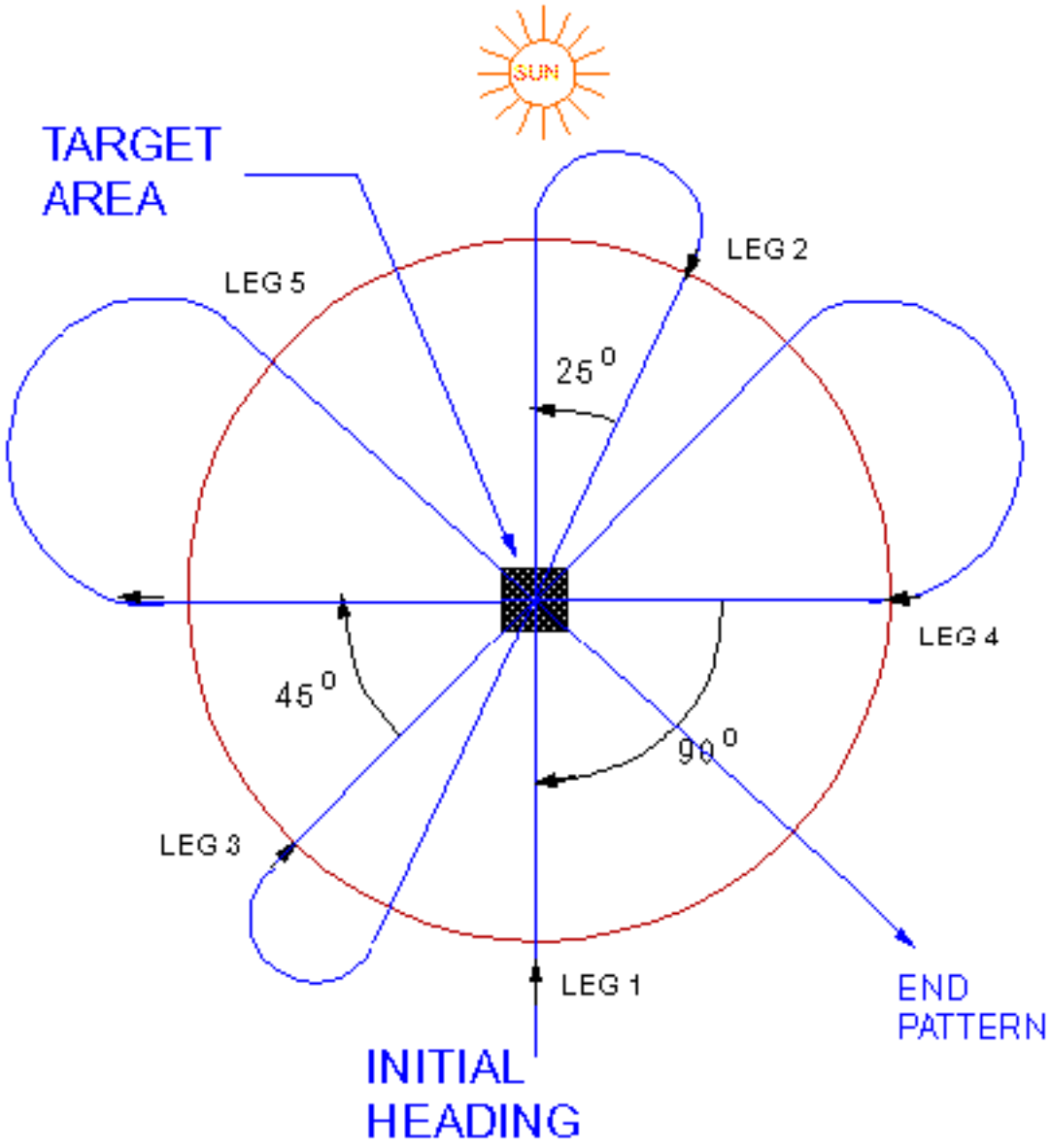


LOUISIANA

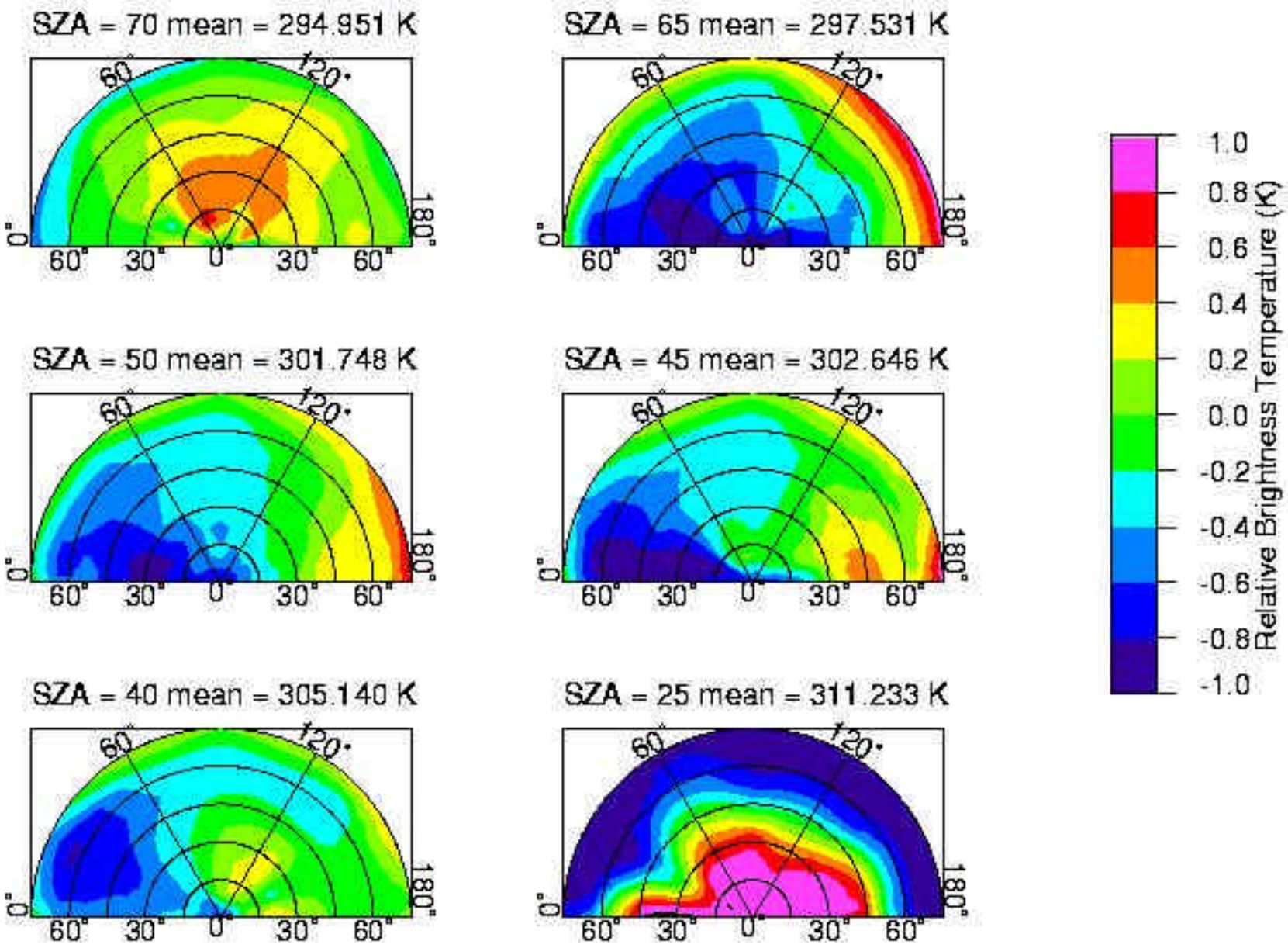

Region B (Flat Land, Julian Day 95294, ~1830 UTC)
MAS Back scatter
MAS Forward scatter
BTMAS > BTGOES-8
BTMAS < BTGOES-8
GOES-8 Reference Temperature (Back scatter)
West
South
−2.0
0.0
2.0
4.0
Brightness Temperature Differences (GOES−8 − MAS)

Helicopter LW ADMs

- CARE, August 1998, morning data
- Fly identical azimuthal flight pattern for every SZA
  - Point radiometer instrument at same ground spot
- Perform correlated Ks to remove limb darkening
  - Flight level 300 meters
- Milo field characteristics
  - 1.2 meters tall crop
  - 0.5 meter spacing between crop rows


SUN
TARGET AREA
LEG 5
LEG 2
25 0
LEG 4
45 0
90 0
LEG 3
LEG 1
END PATTERN
INITIAL HEADING

CARE BRDF - Milo



Helicopter ADM conclusions

- Azimuthal signal increases as solar heating increases or with lower solar zenith angles
- Forward scatter is colder relative to back scatter

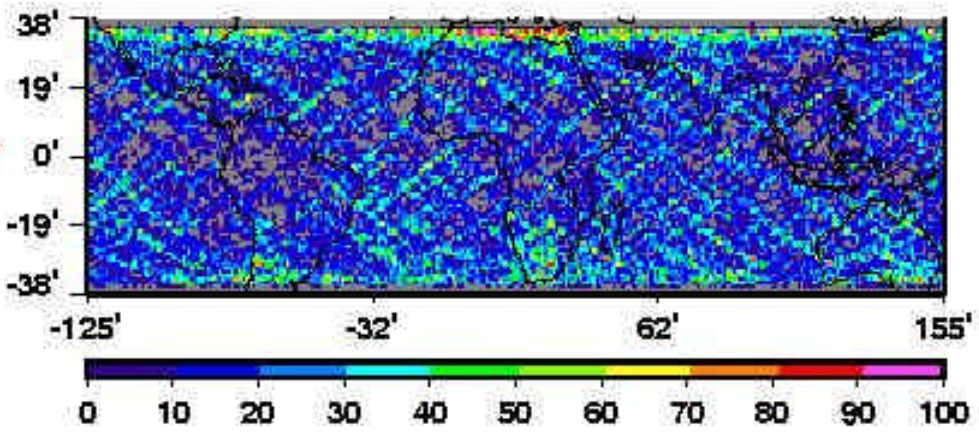
TRMM CERES-SSF

- January - August 1998, RAPS (10km nadir), (edition 2A)
- 9 azimuth bins, every 20°,
  - 1=10° (forward scatter)
- 5 view angle bins, every 15°
  - 1=near nadir
- 4 cloud amount bins, 0-5, 5-50, 50-95, 95-100%,
  - 1=clear, 2=partly cloudy, 3=mostly cloudy, 4=overcast
  - Cloud amount determined from VIRS cloud mask
- 4 local time bins (LCT bin)
  - 1=sunrise, 2=before noon, 3=afternoon, 4=sunset

Clear
VZN summed
AZ bin # 1
Lct bin # 3

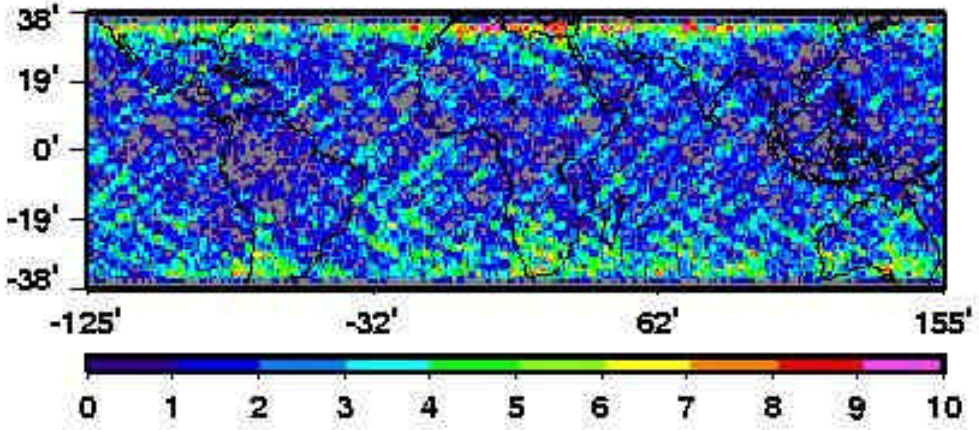
# of pixels

per 1° region out of 80 RAPS days



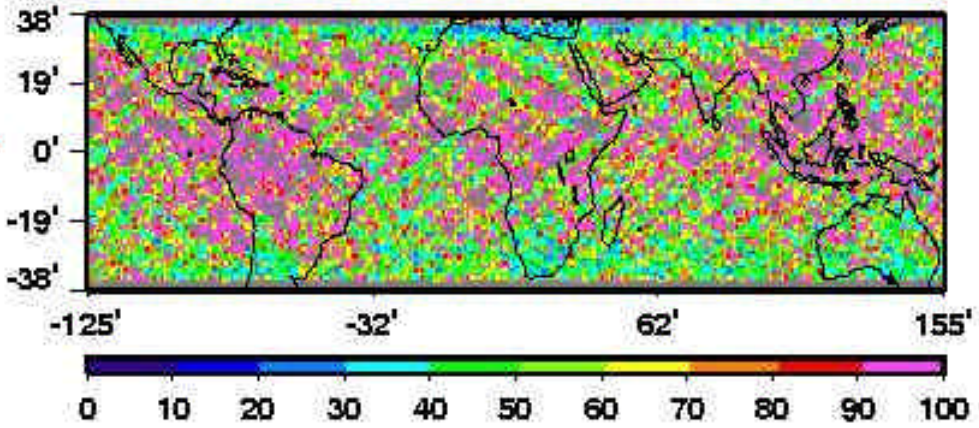
# of days

out of 80 days sampled



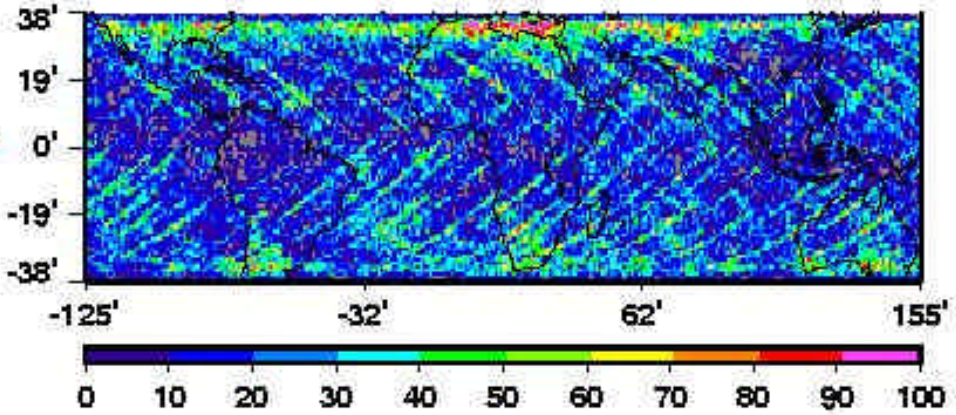
Highest %

% of pixels that the highest sampled day has

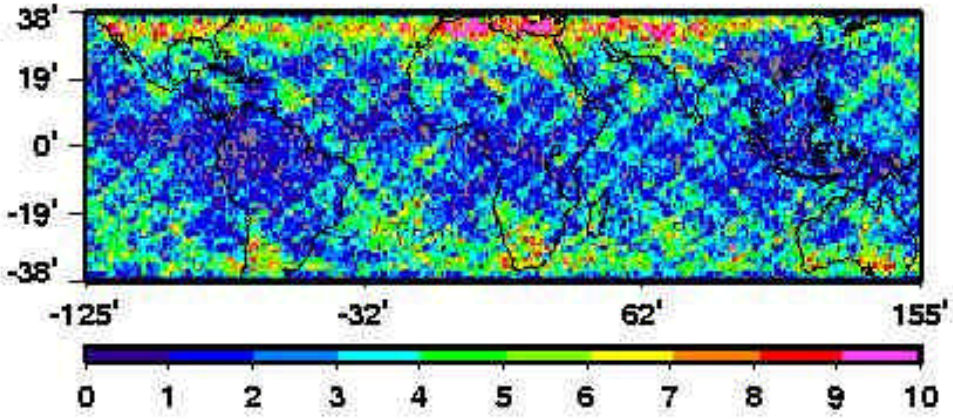


Clear
VZN summed
AZ bin # 5
Lct bin # 3

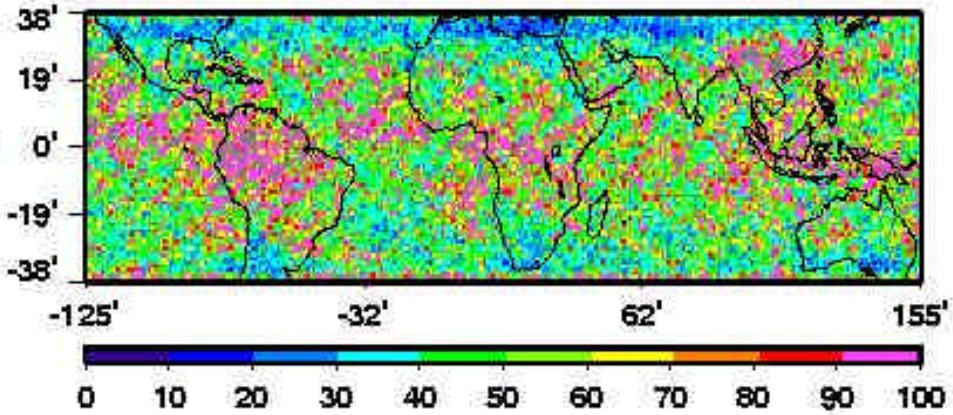
# of pixels



# of days



Highest %



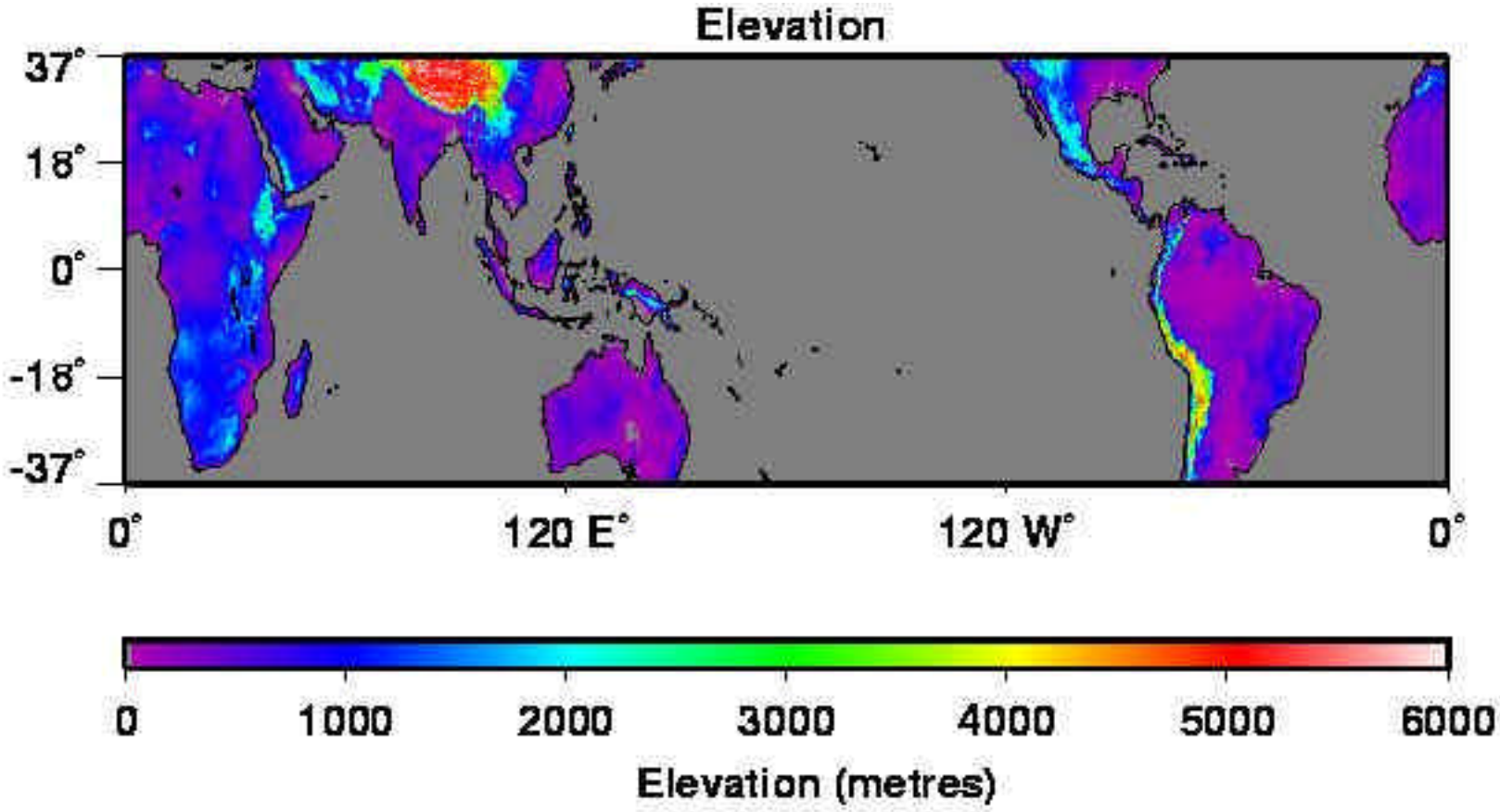
Regional Multi-angle sampling Conclusions

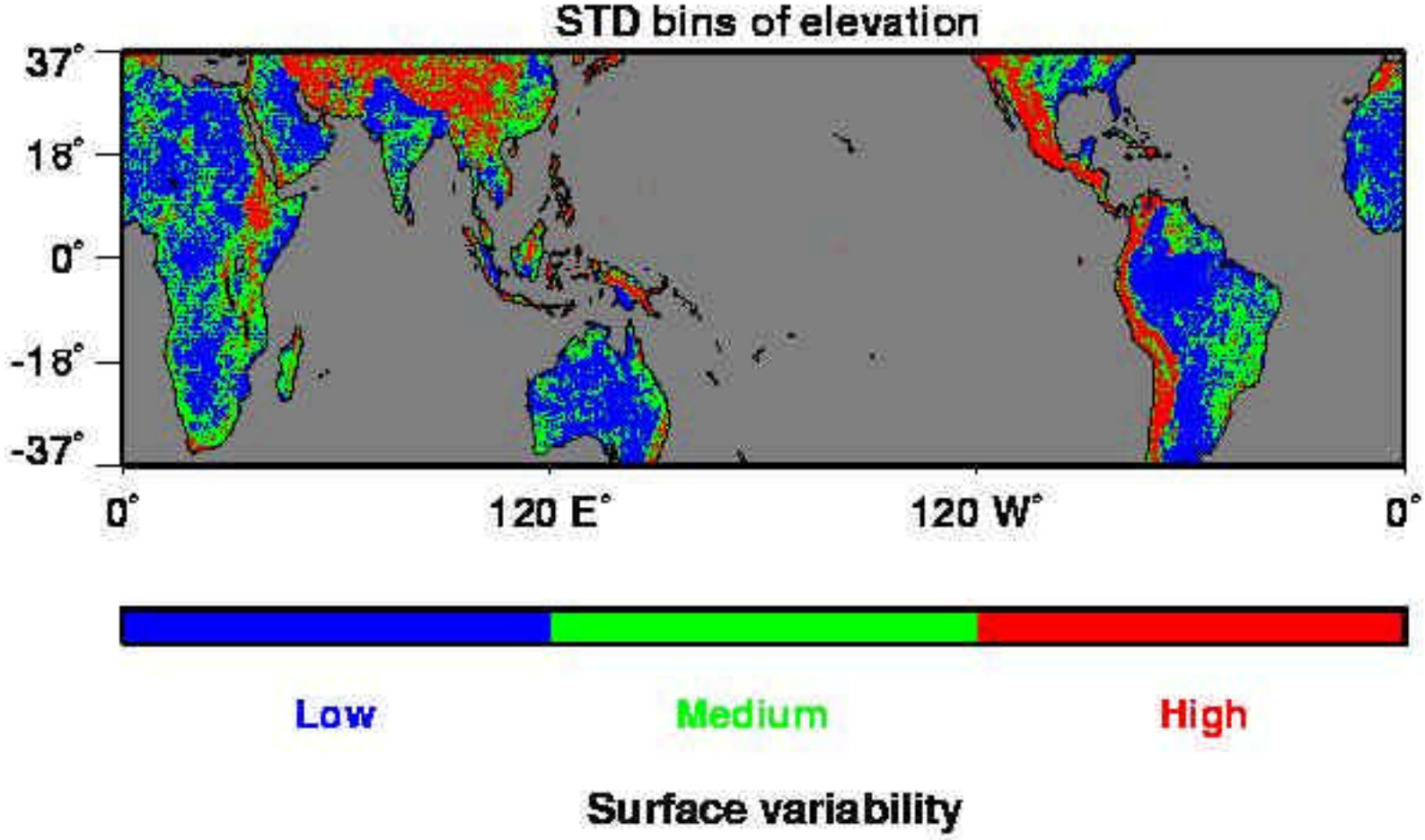
- TRMM, 35° precessing orbit
  - 0 - 30°N 30°N - 37°N 0° - 37°N
  - 70% 30% 100% pixels
  - 83% 17% 100% area
- In the tropics only a few days are sampled out of 80 RAPS days
- In the tropics the dominant day has over 50% of the pixels out of < 50 pixels
- Regional angular models not possible with TRMM CERES SSF data set

Topography Bins

- ETOPO5 data base
- 5’ minute resolution (~10 km)
- Take standard deviation of 3x3 elevations

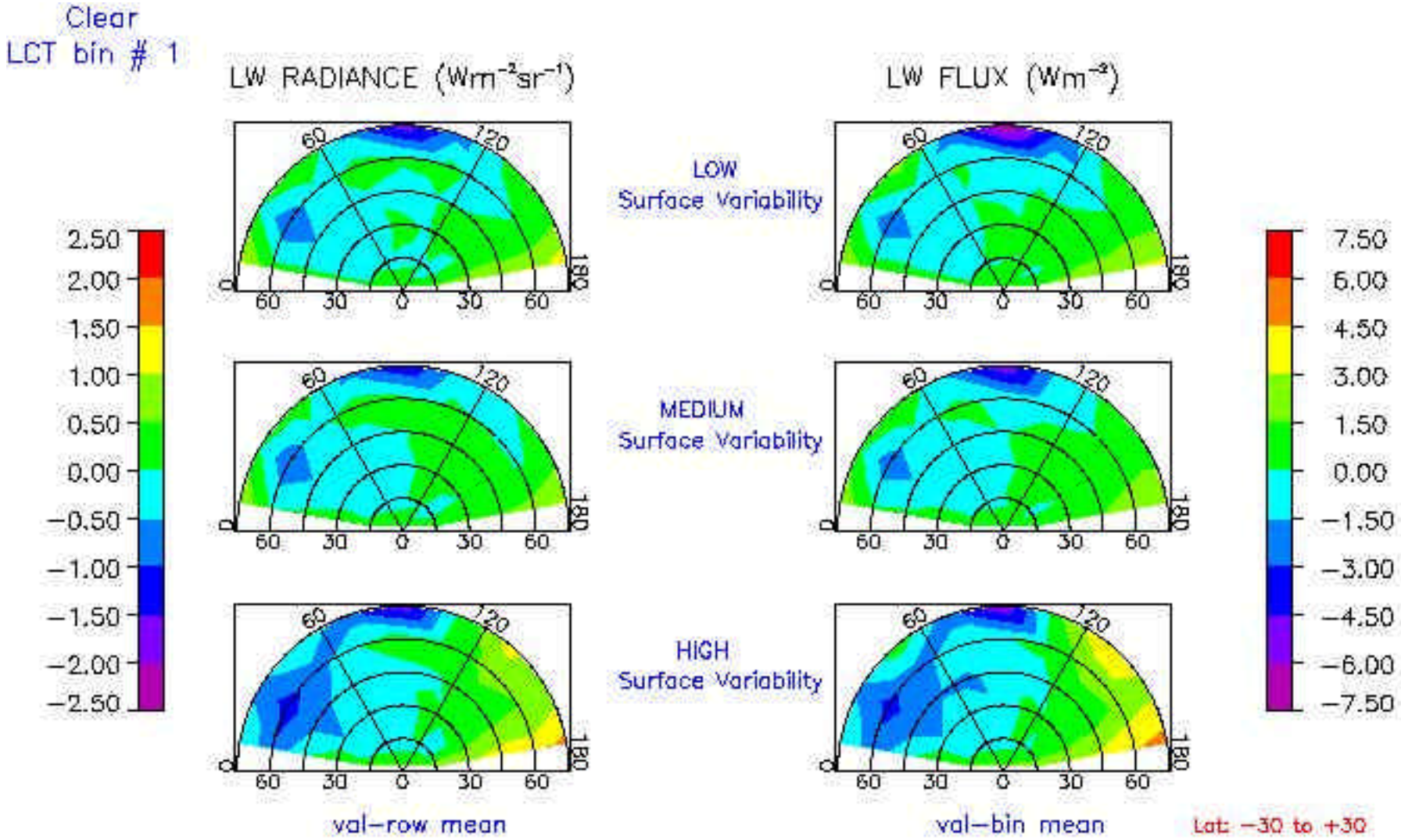
• 0-10 meters	low variability	45% of all land
• 10-50 meters	medium variability	35%
• >50 meters	high variability	25%

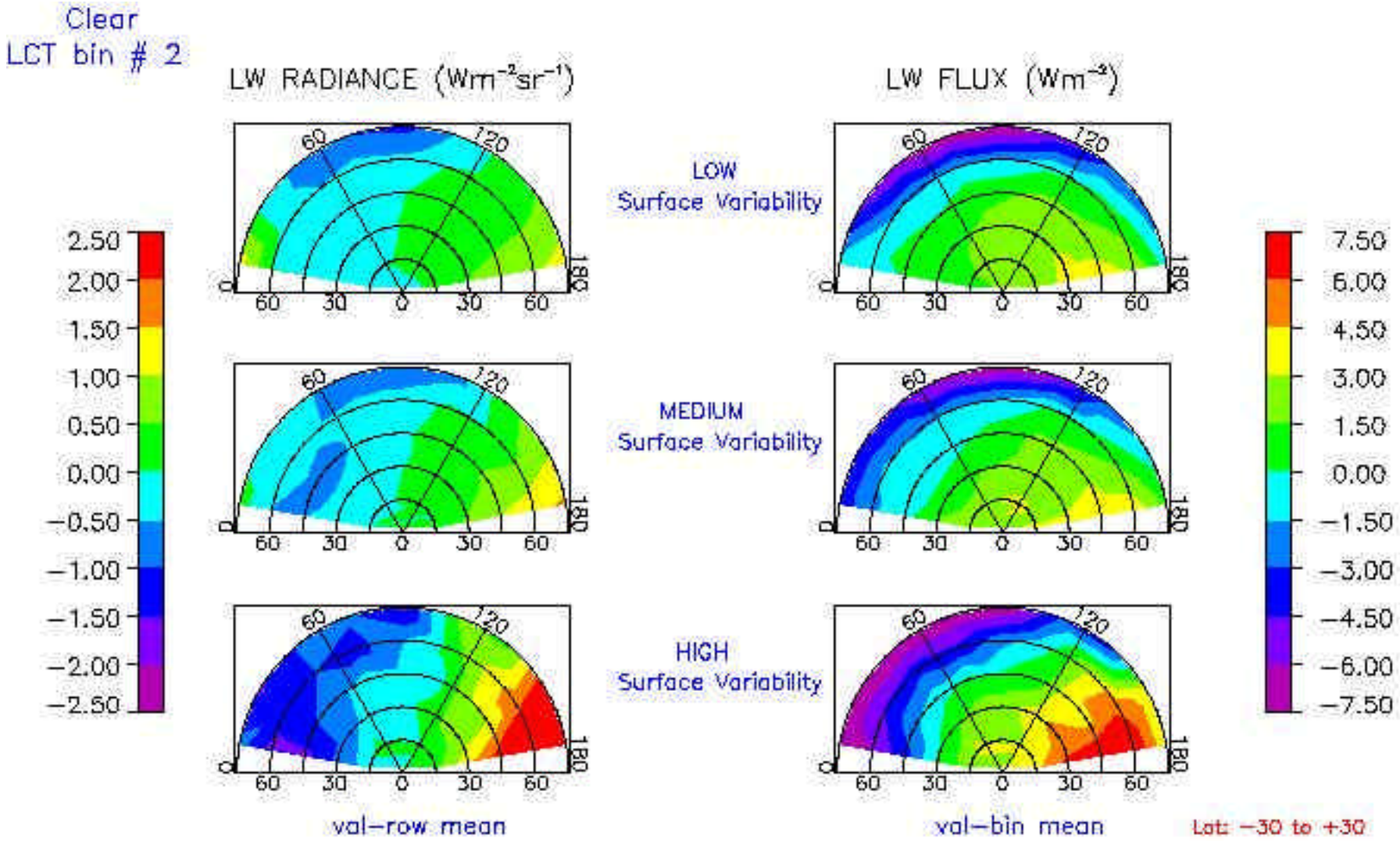

Elevation
37°
18°
0°
-18°
-37°
0°
120 E°
120 W°
0°
0
1000
2000
3000
4000
5000
6000
Elevation (metres)

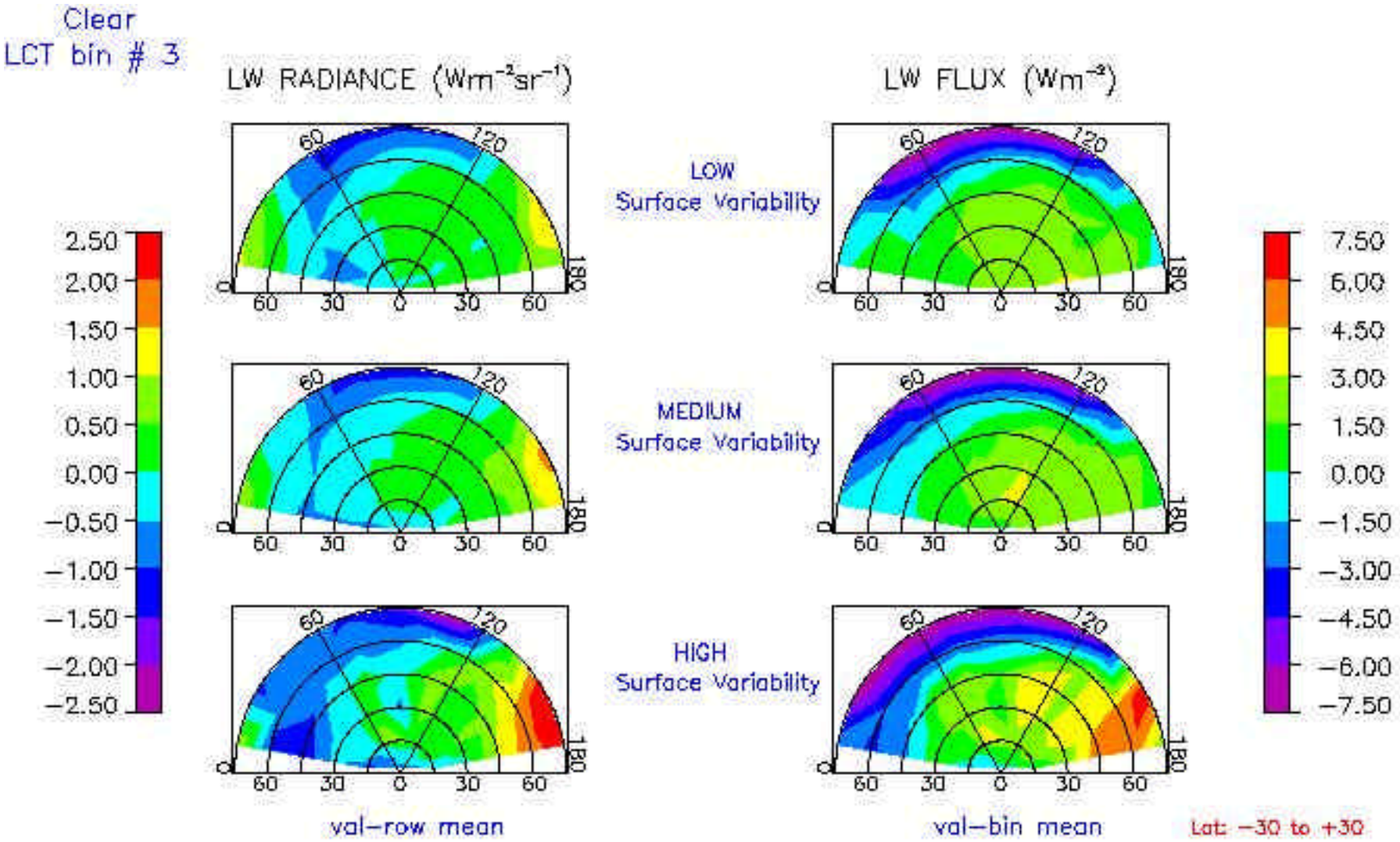

STD bins of elevation
37°
18°
0°
-18°
-37°
0°
120 E°
120 W°
0°
Low
Medium
High
Surface variability

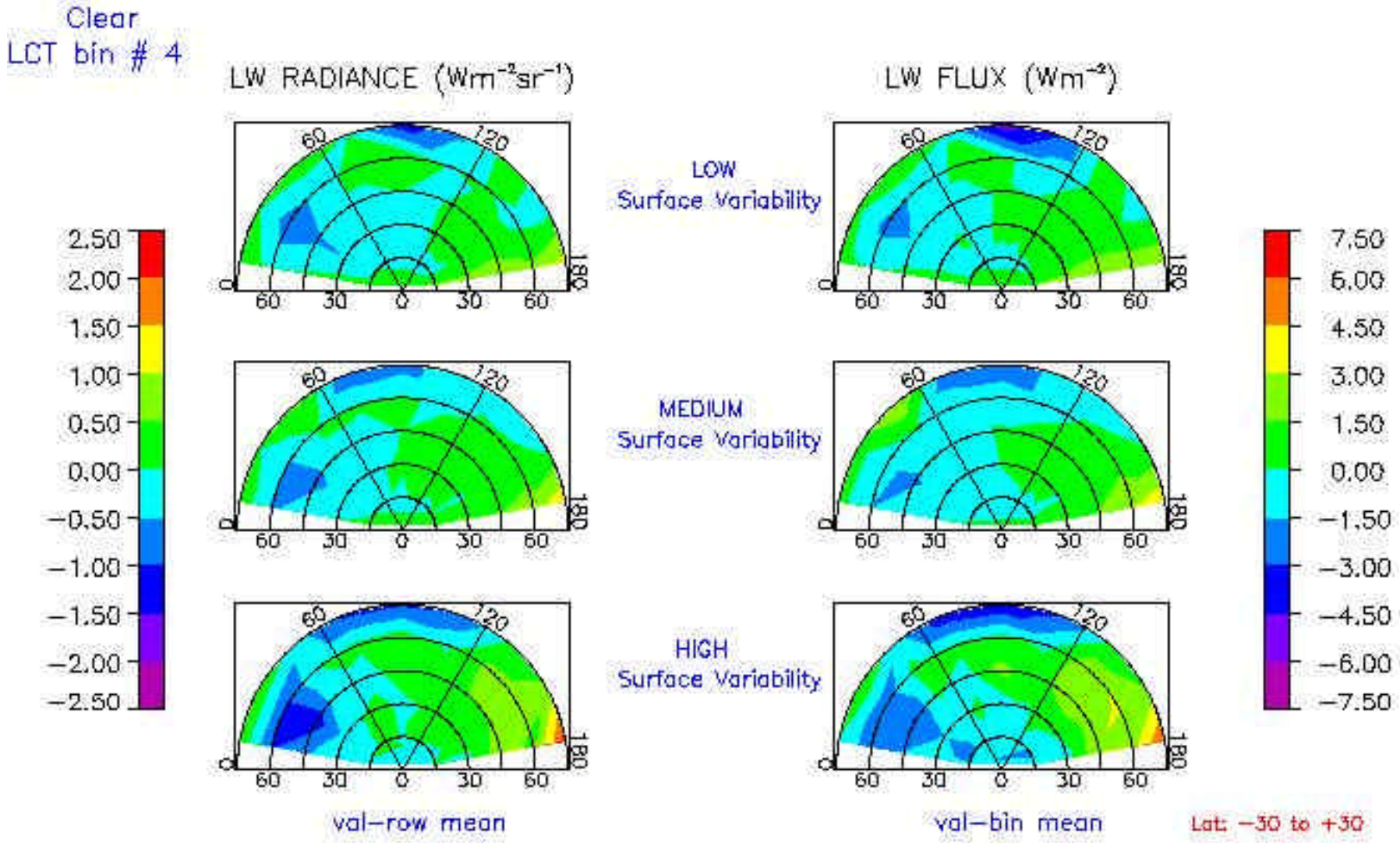
ADM plots

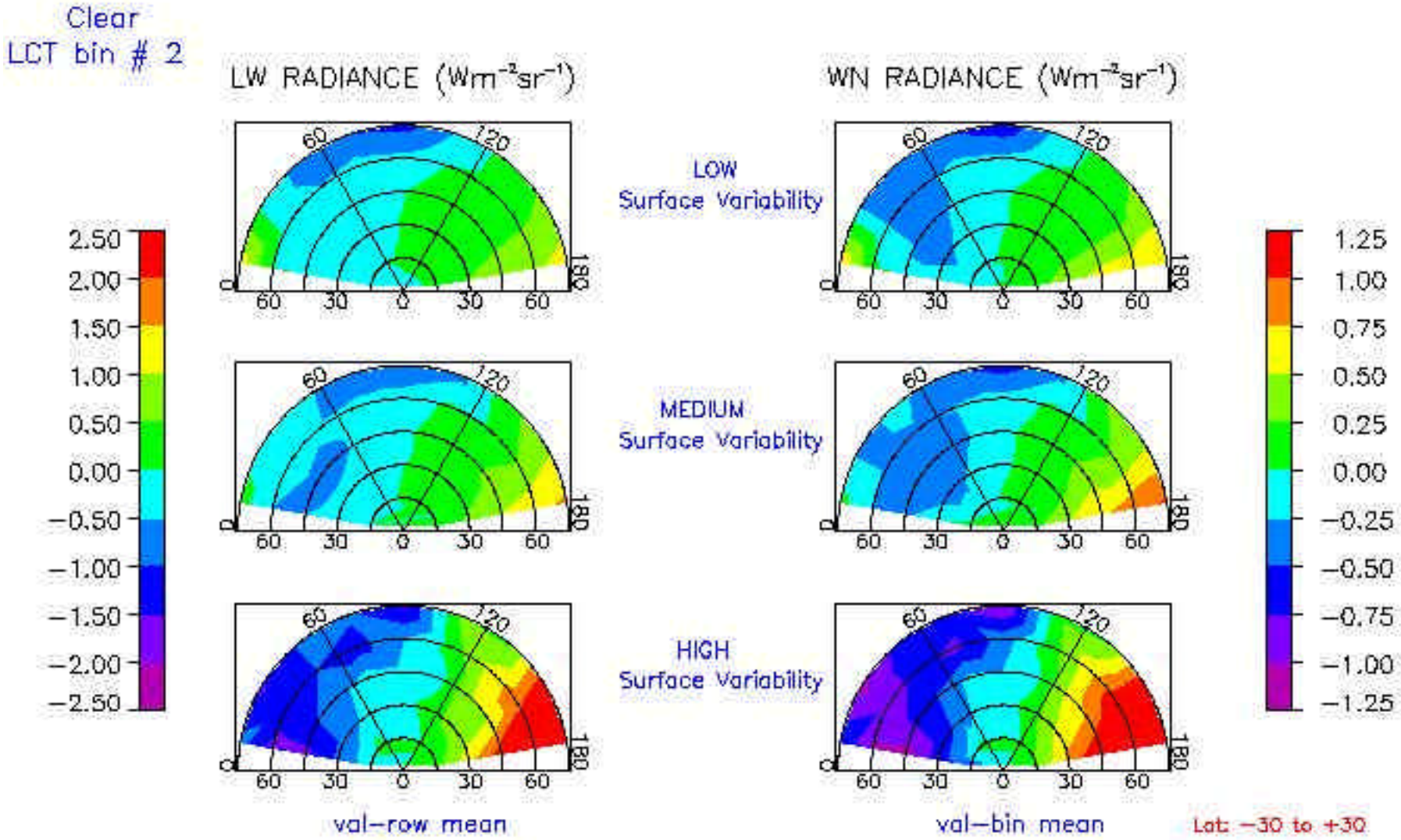
- For radiances, subtract radiances from the mean view angle radiance
- For fluxes, subtract fluxes from the mean
  - CERES limb darkening models applied (edition 2a)
- To convert longwave radiances into temperatures
  - $T(K°) = (R/\sigma)^{1/4}$,where $R = \pi \, rad(Wm^{-2} \, sr^{-1})$
- To convert window radiances into temperatures
  - Use plank function with central wavelength of 10.0μm
  - Use 3.7μm bandwidth
- For temperatures, use radiance approach

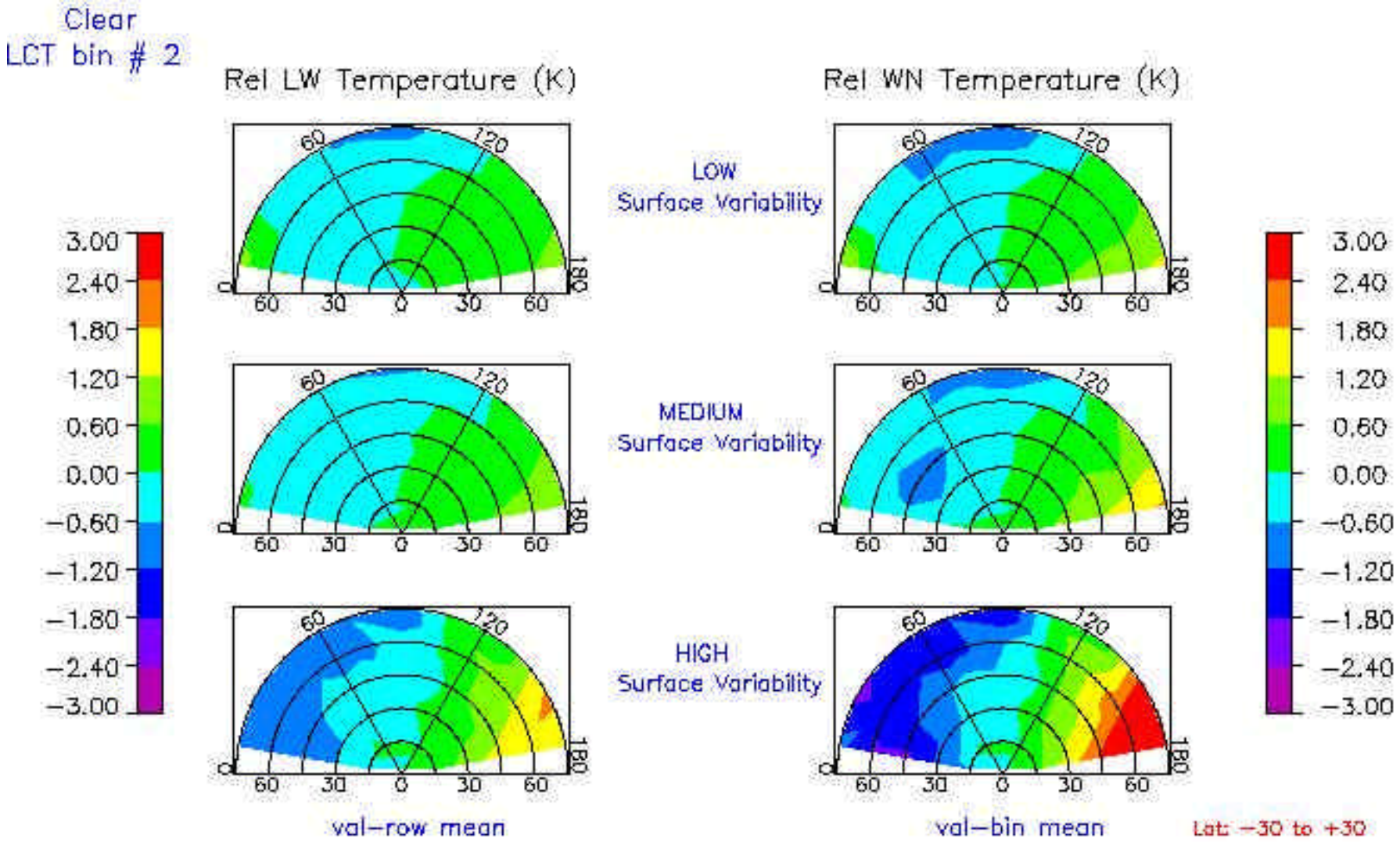

Clear
LCT bin # 1
LW RADIANCE (Wm⁻²sr⁻¹)
LW FLUX (Wm⁻²)
LOW
Surface Variability
MEDIUM
Surface Variability
HIGH
Surface Variability
2.50
2.00
1.50
1.00
0.50
0.00
−0.50
−1.00
−1.50
−2.00
−2.50
7.50
6.00
4.50
3.00
1.50
0.00
−1.50
−3.00
−4.50
−6.00
−7.50
60
120
0
180
60
30
0
30
60
val−row mean
val−bin mean
Lat: −30 to +30


Clear
LCT bin # 2
LW RADIANCE (Wm⁻²sr⁻¹)
LW FLUX (Wm⁻²)
LOW
Surface Variability
MEDIUM
Surface Variability
HIGH
Surface Variability
2.50
2.00
1.50
1.00
0.50
0.00
−0.50
−1.00
−1.50
−2.00
−2.50
7.50
6.00
4.50
3.00
1.50
0.00
−1.50
−3.00
−4.50
−6.00
−7.50
60
120
180
0
60
30
0
30
60
val−row mean
val−bin mean
Lat: −30 to +30

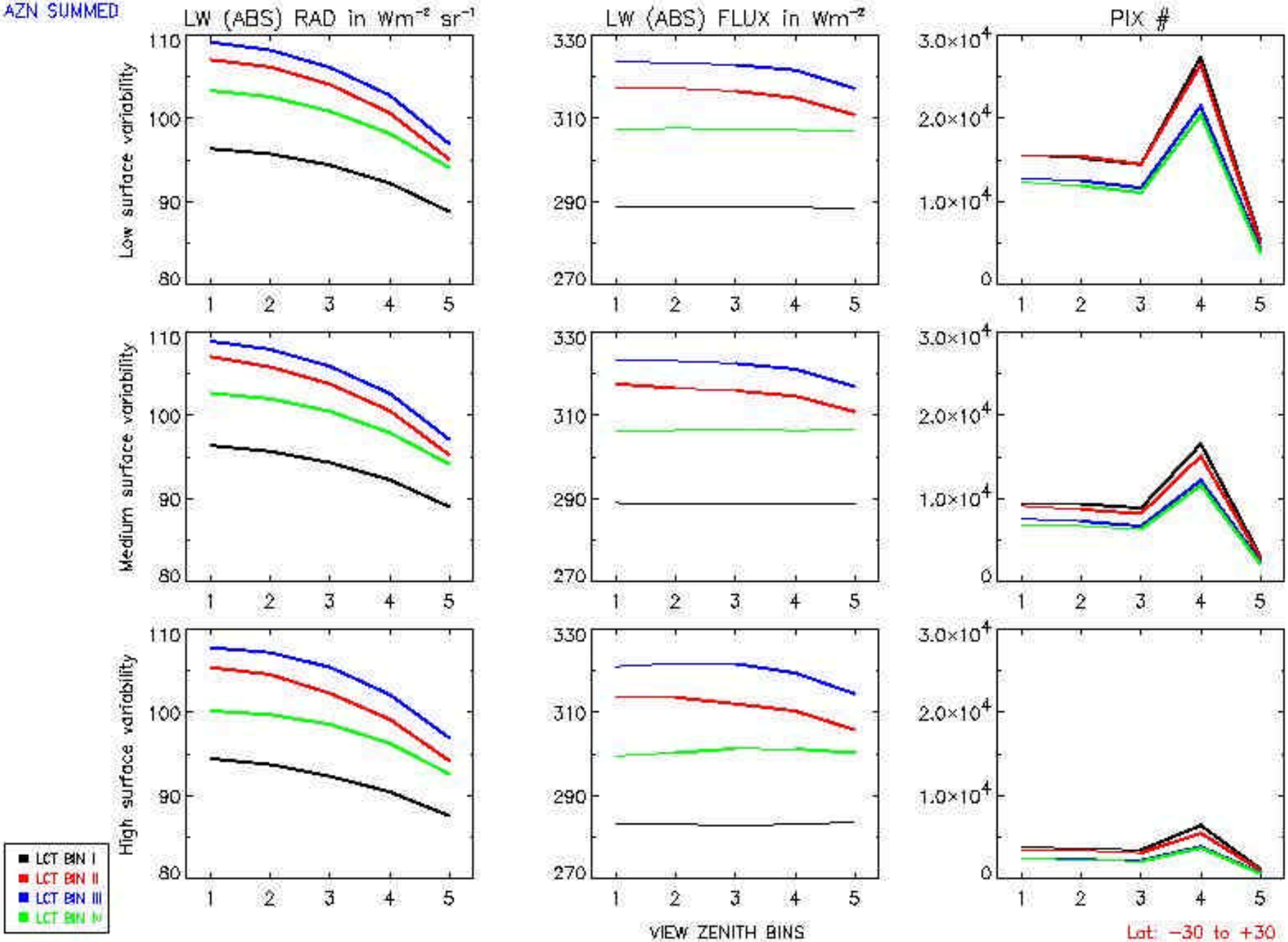

Clear
LCT bin # 3
LW RADIANCE (Wm⁻²sr⁻¹)
LW FLUX (Wm⁻²)
LOW
Surface Variability
MEDIUM
Surface Variability
HIGH
Surface Variability
2.50
2.00
1.50
1.00
0.50
0.00
−0.50
−1.00
−1.50
−2.00
−2.50
7.50
6.00
4.50
3.00
1.50
0.00
−1.50
−3.00
−4.50
−6.00
−7.50
60
120
180
0
60
30
0
30
60
val−row mean
val−bin mean
Lat: −30 to +30


Clear
LCT bin # 4
LW RADIANCE (Wm⁻²sr⁻¹)
LW FLUX (Wm⁻²)
LOW
Surface Variability
MEDIUM
Surface Variability
HIGH
Surface Variability
2.50
2.00
1.50
1.00
0.50
0.00
−0.50
−1.00
−1.50
−2.00
−2.50
7.50
6.00
4.50
3.00
1.50
0.00
−1.50
−3.00
−4.50
−6.00
−7.50
60
120
180
0
60
30
0
30
60
val−row mean
val−bin mean
Lat: −30 to +30


Clear
LCT bin # 2
LW RADIANCE (Wm⁻²sr⁻¹)
WN RADIANCE (Wm⁻²sr⁻¹)
LOW
Surface Variability
MEDIUM
Surface Variability
HIGH
Surface Variability
2.50
2.00
1.50
1.00
0.50
0.00
−0.50
−1.00
−1.50
−2.00
−2.50
1.25
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
−1.25
60
120
180
0
60
30
0
30
60
val−row mean
val−bin mean
Lat: −30 to +30

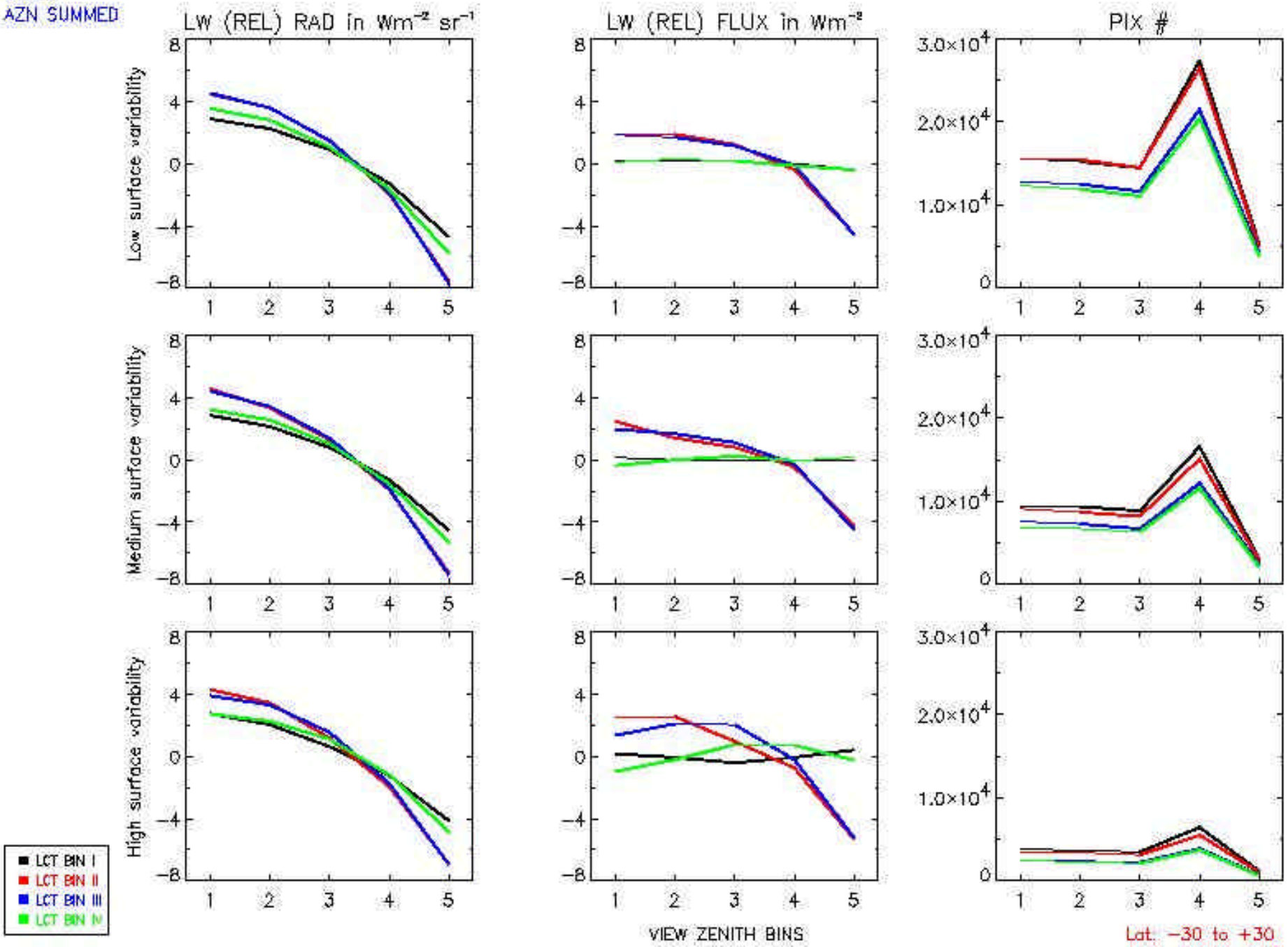

Clear
LCT bin # 2
Rel LW Temperature (K)
Rel WN Temperature (K)
LOW
Surface Variability
MEDIUM
Surface Variability
HIGH
Surface Variability
3.00
2.40
1.80
1.20
0.60
0.00
−0.60
−1.20
−1.80
−2.40
−3.00
60
120
180
0
60
30
0
30
60
val−row mean
val−bin mean
Lat: −30 to +30

CLEAR
AZN SUMMED



Lat: −30 to +30

CLEAR
AZN SUMMED

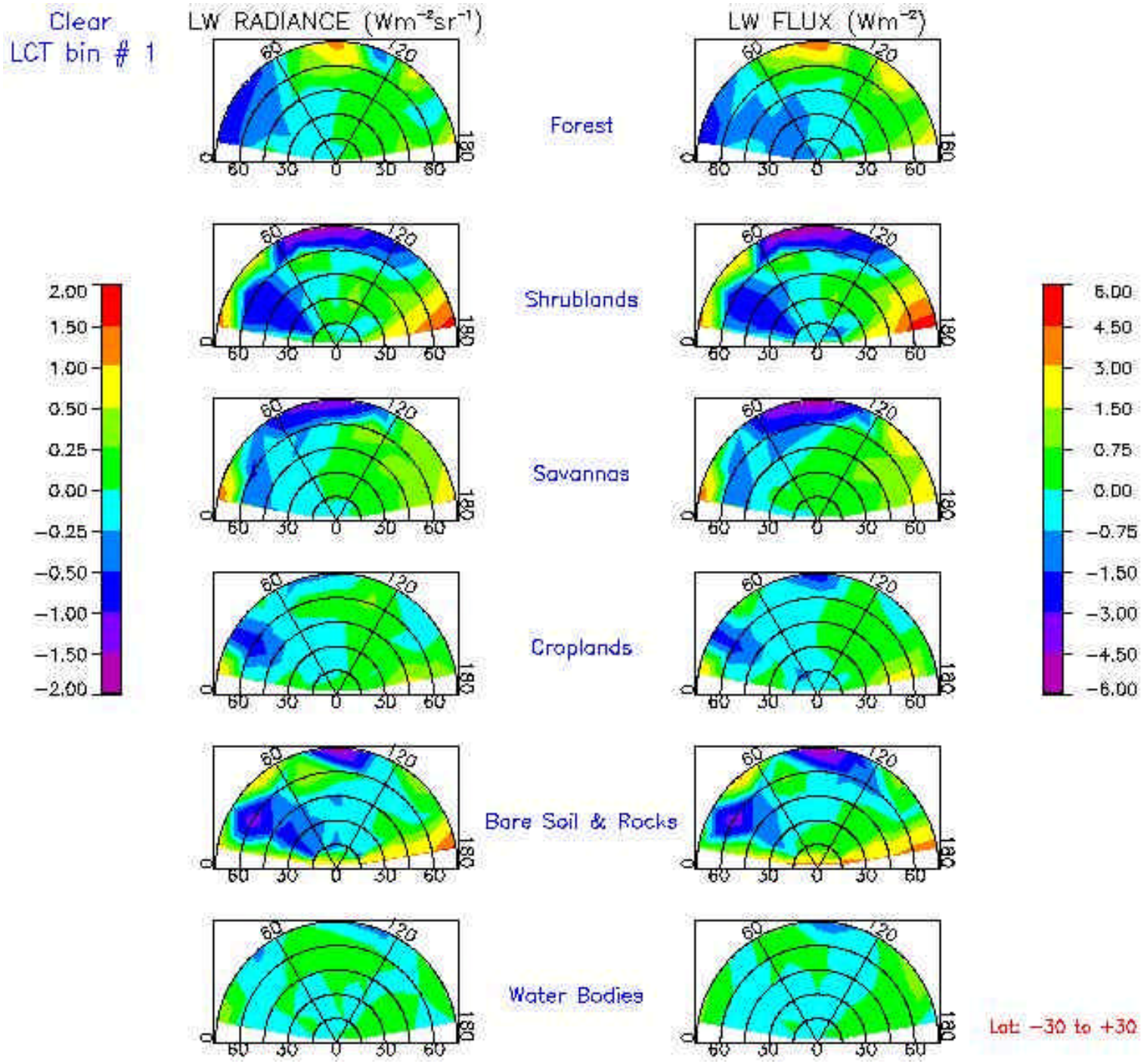


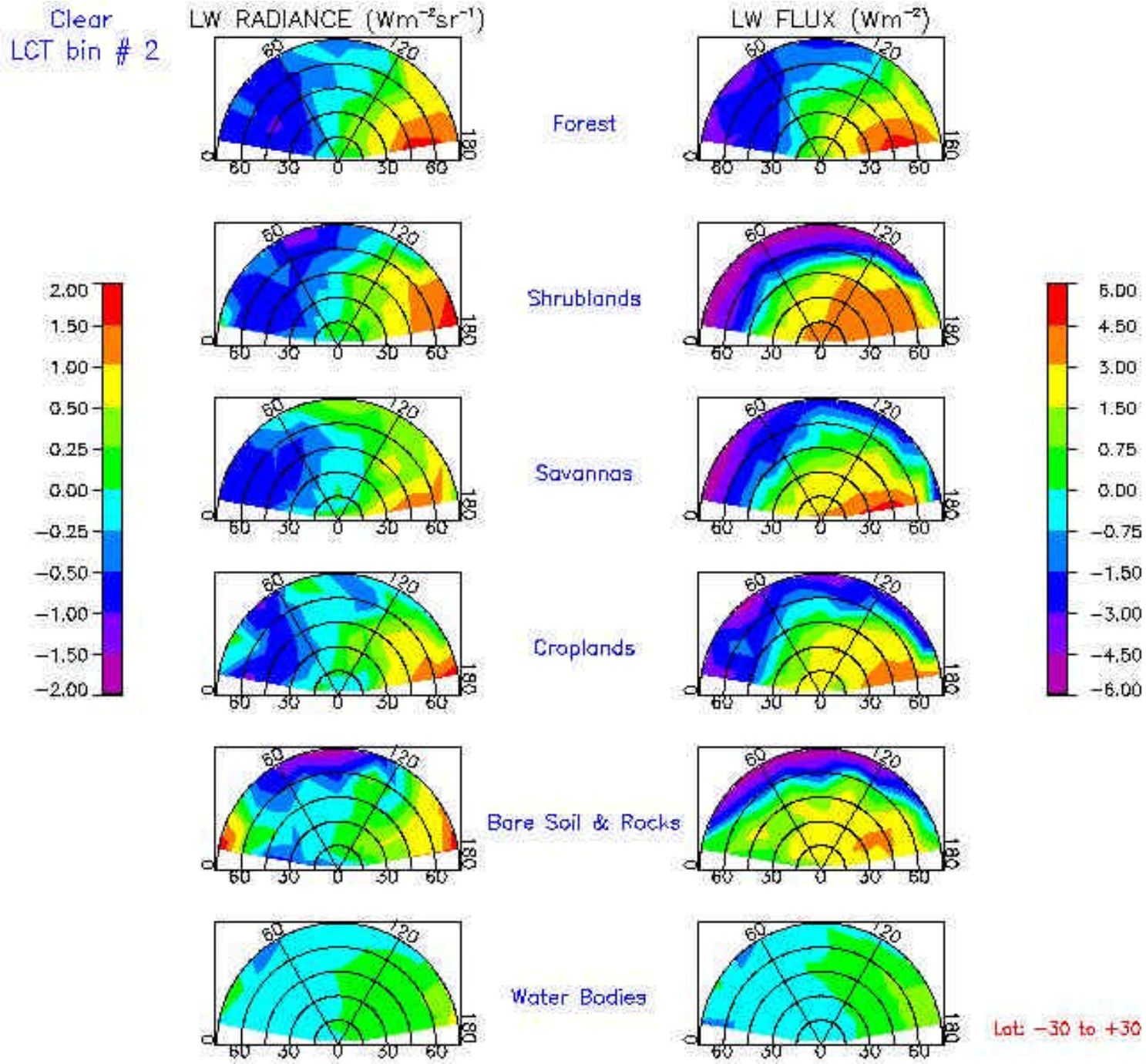
Topography conclusions

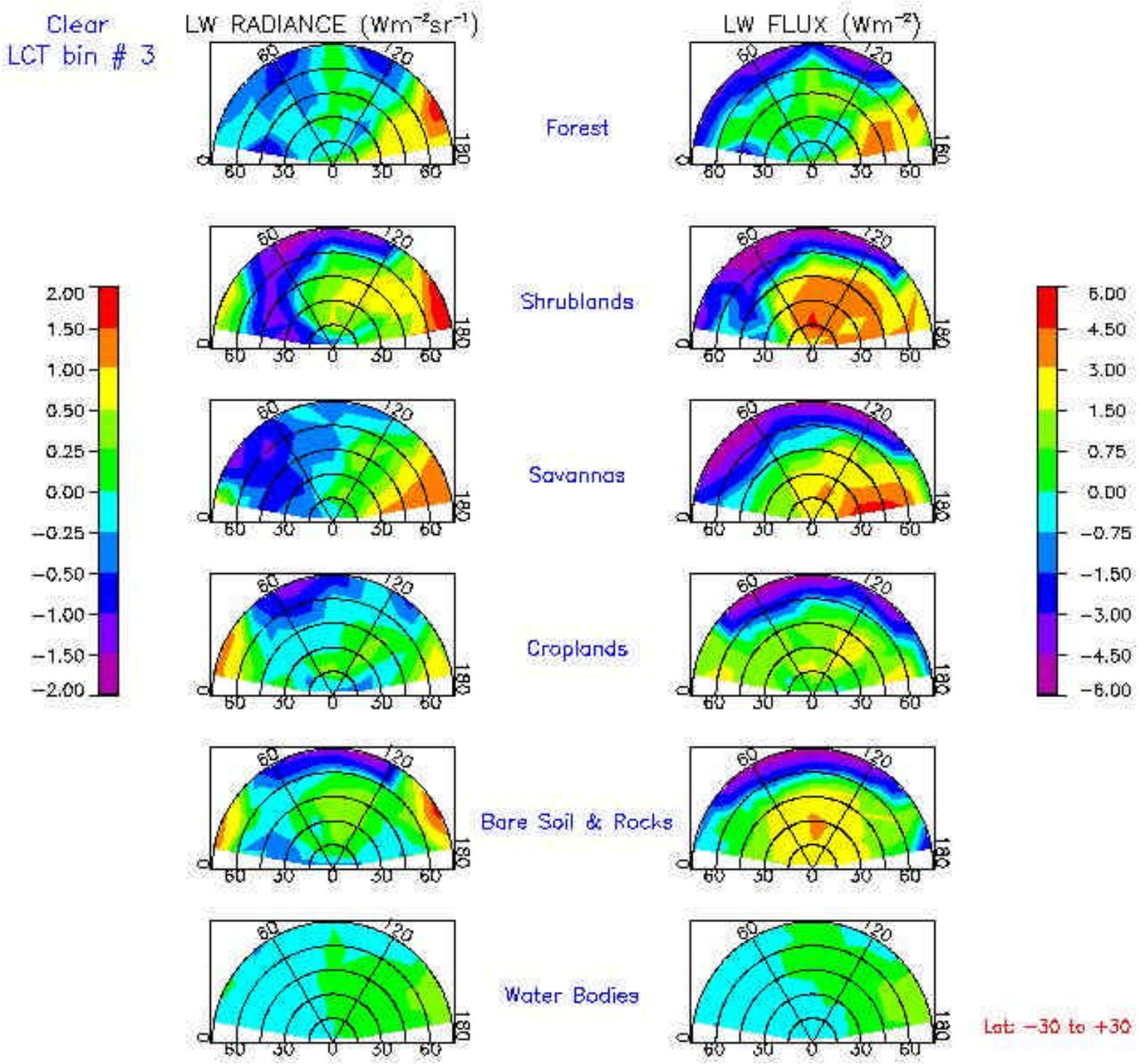
- Forward scatter is colder than backscatter IR radiation
- Azimuthal signal increases with increased surface roughness
- Azimuthal signal greater near noon
- Up to 2.5° K longwave and 5.0° K window temperature difference between backward and forward scattering
- Greater limb darkening near noon

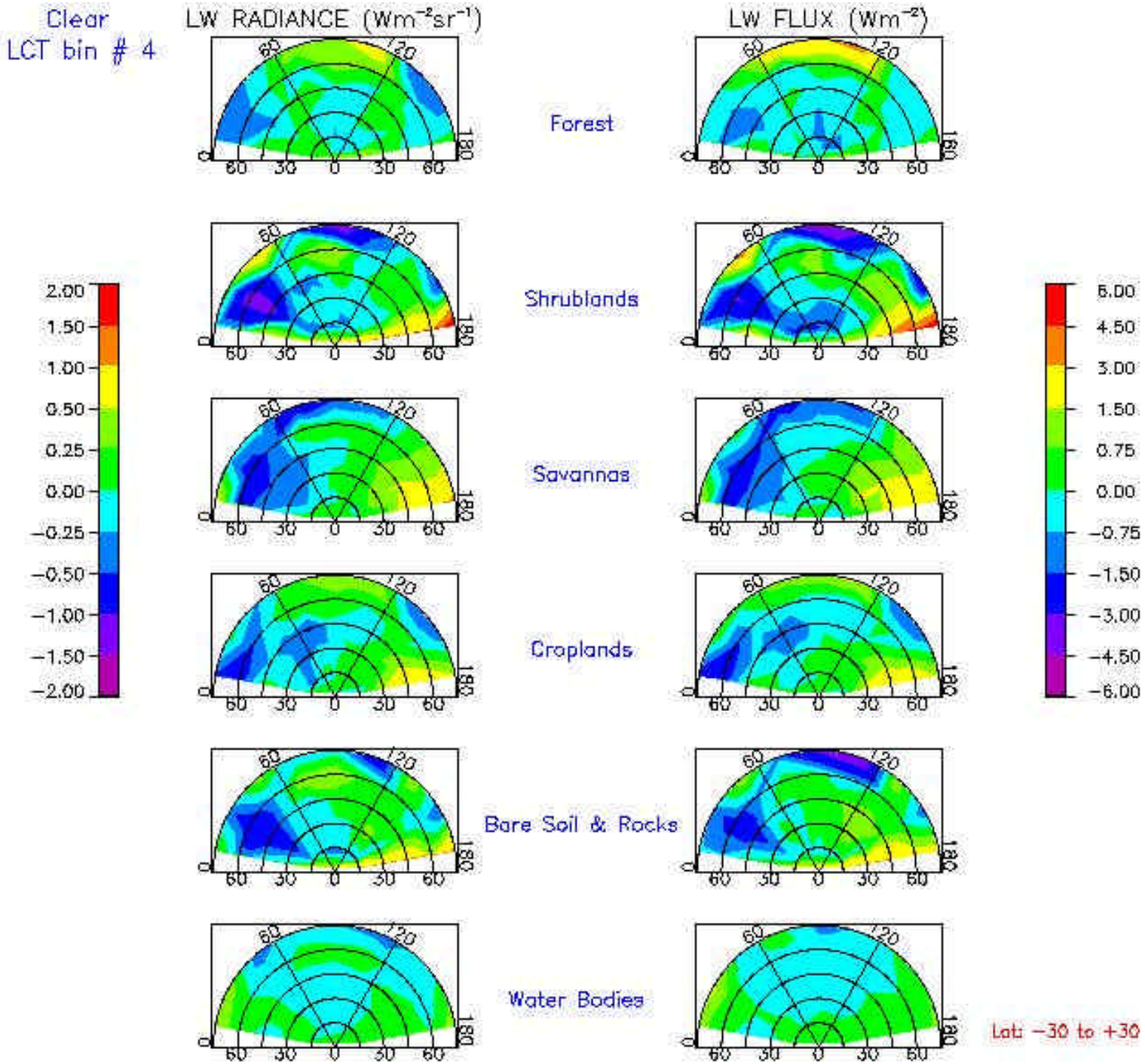
IGBP Bins

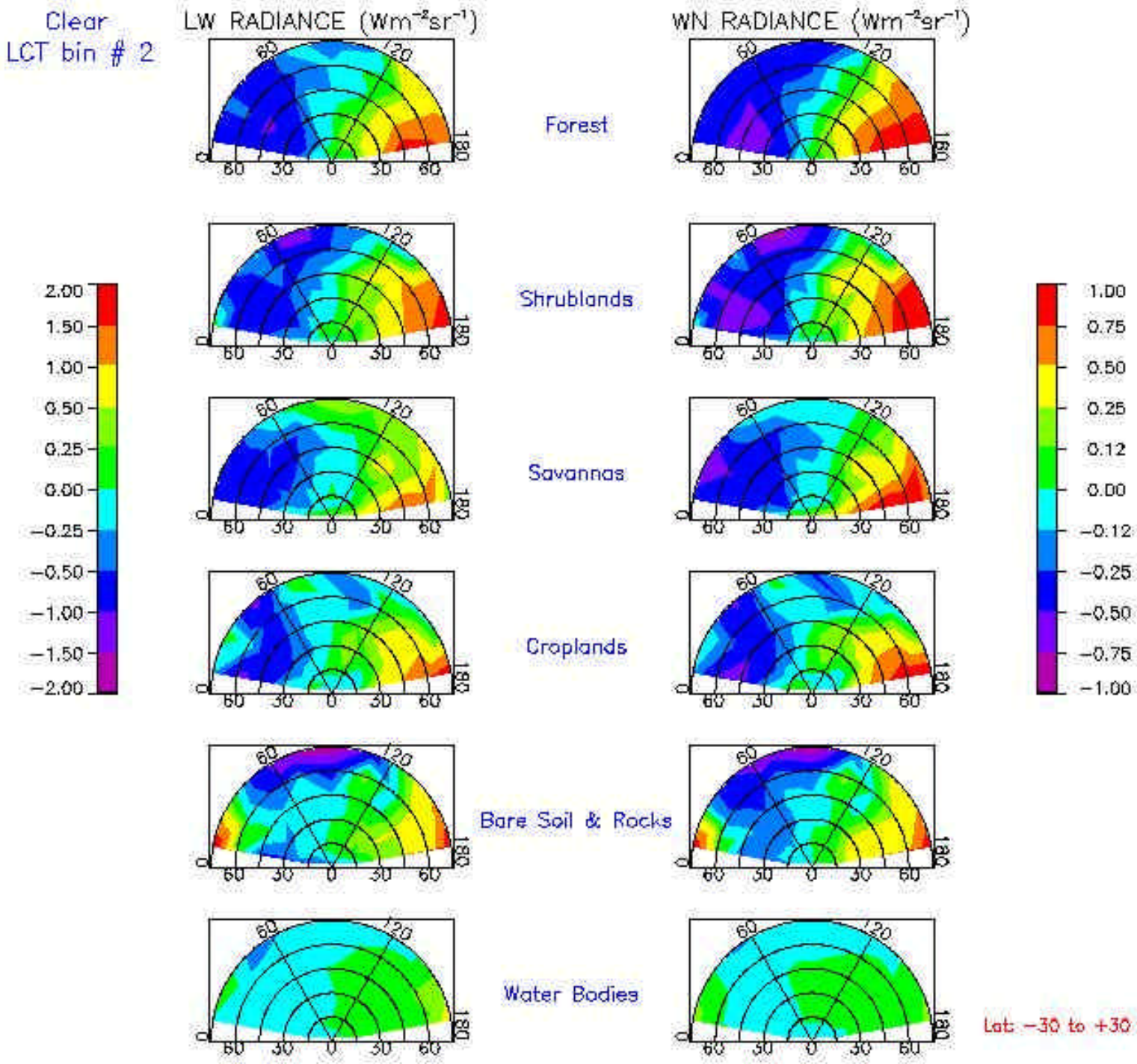
- 6 IGBP bins
- 1 - all forests
- 2 - open and closed shrublands
- 3 - all savannas and grasslands
- 4 - all croplands
- 5 - bare soil and rocks
- 6 - water bodies

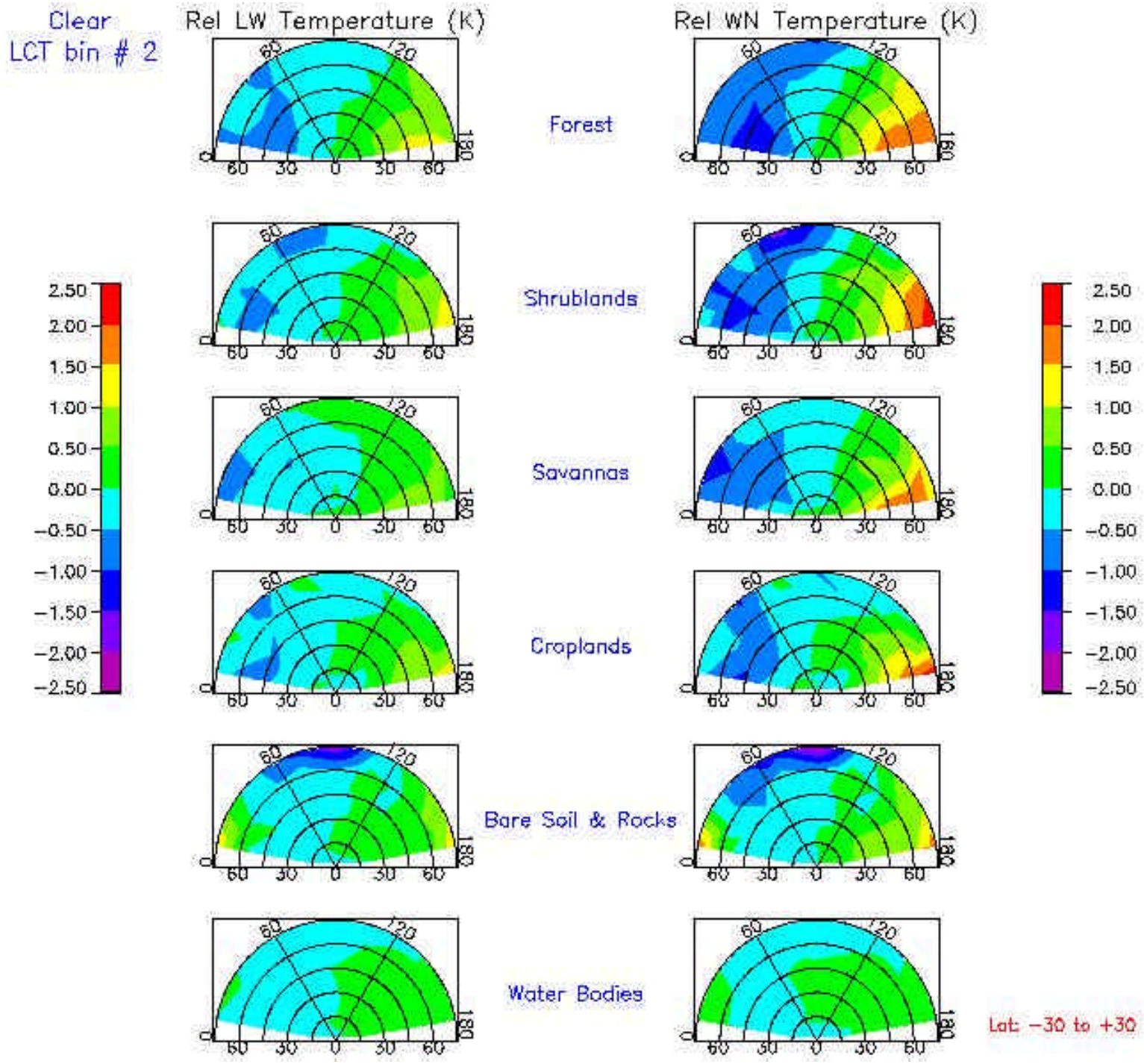

Clear
LCT bin # 1
LW RADIANCE (Wm⁻²sr⁻¹)
LW FLUX (Wm⁻²)
Forest
Shrublands
Savannas
Croplands
Bare Soil & Rocks
Water Bodies
2.00
1.50
1.00
0.50
0.25
0.00
−0.25
−0.50
−1.00
−1.50
−2.00
6.00
4.50
3.00
1.50
0.75
0.00
−0.75
−1.50
−3.00
−4.50
−6.00
Lat: −30 to +30

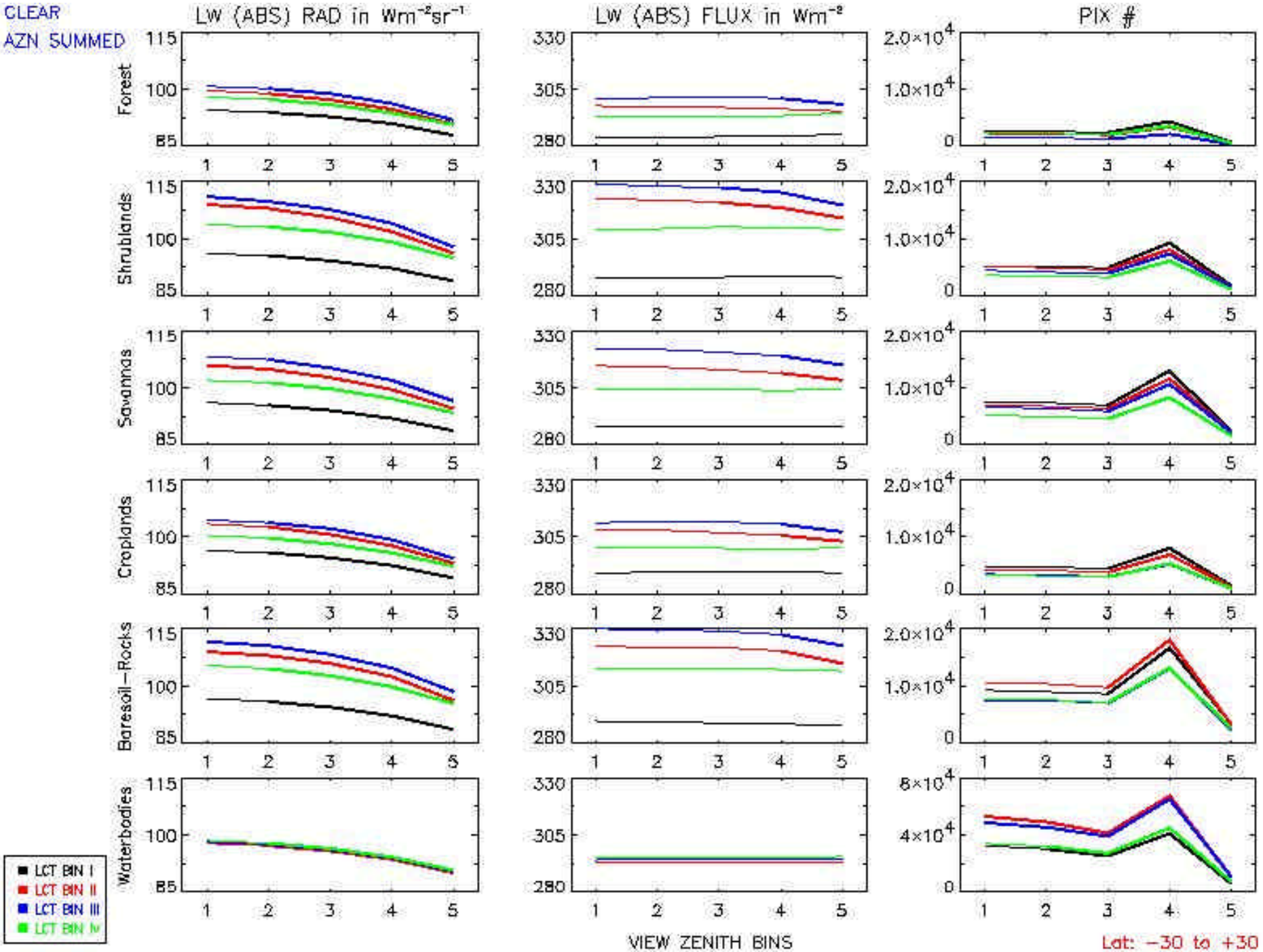

Clear
LCT bin # 2
LW RADIANCE (Wm⁻²sr⁻¹)
LW FLUX (Wm⁻²)
Forest
Shrublands
Savannas
Croplands
Bare Soil & Rocks
Water Bodies
2.00
1.50
1.00
0.50
0.25
0.00
−0.25
−0.50
−1.00
−1.50
−2.00
6.00
4.50
3.00
1.50
0.75
0.00
−0.75
−1.50
−3.00
−4.50
−6.00
Lat: −30 to +30

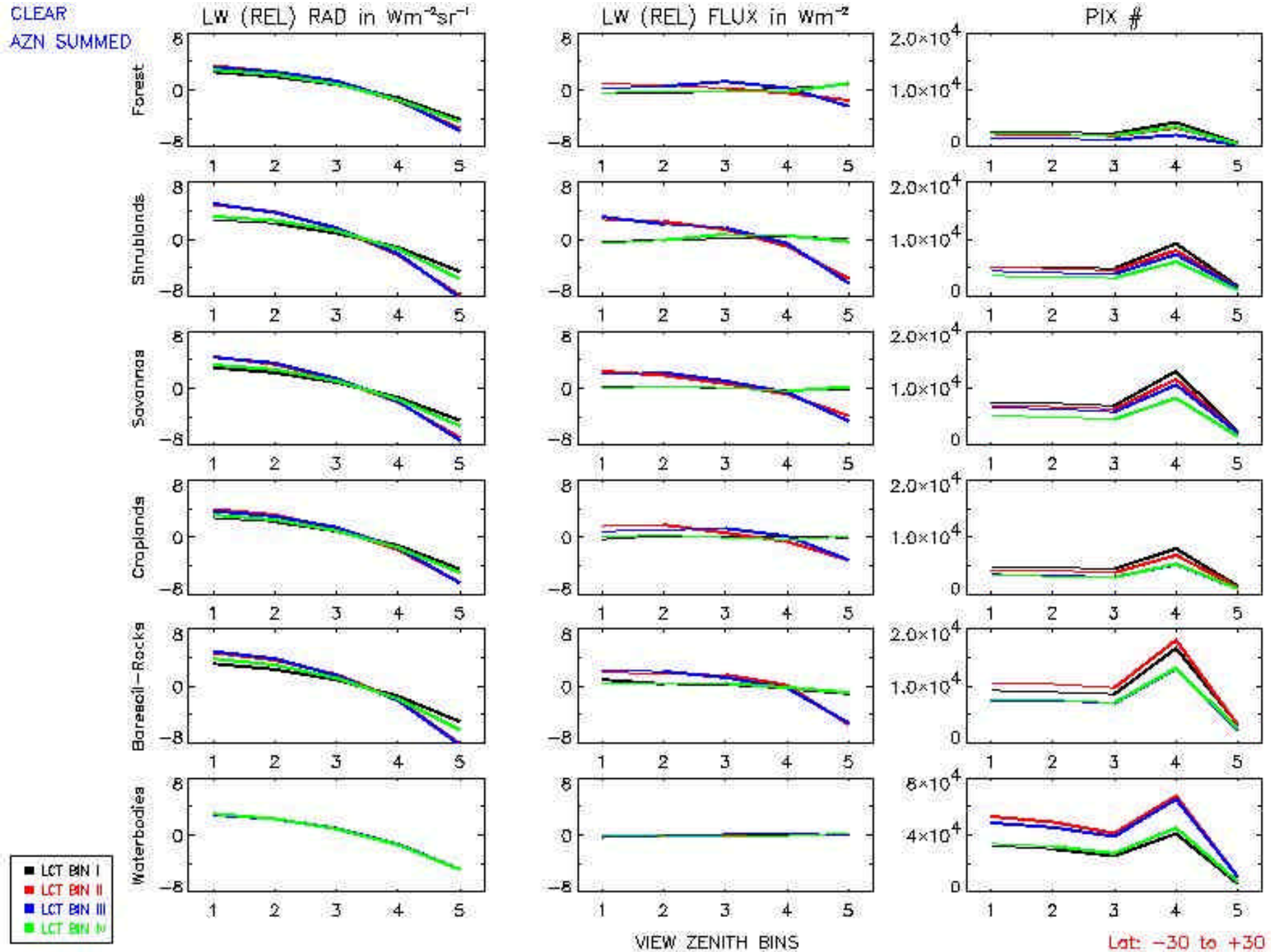

Clear
LCT bin # 3
LW RADIANCE (Wm⁻²sr⁻¹)
LW FLUX (Wm⁻²)
Forest
Shrublands
Savannas
Croplands
Bare Soil & Rocks
Water Bodies
2.00
1.50
1.00
0.50
0.25
0.00
−0.25
−0.50
−1.00
−1.50
−2.00
6.00
4.50
3.00
1.50
0.75
0.00
−0.75
−1.50
−3.00
−4.50
−6.00
Lat: −30 to +30

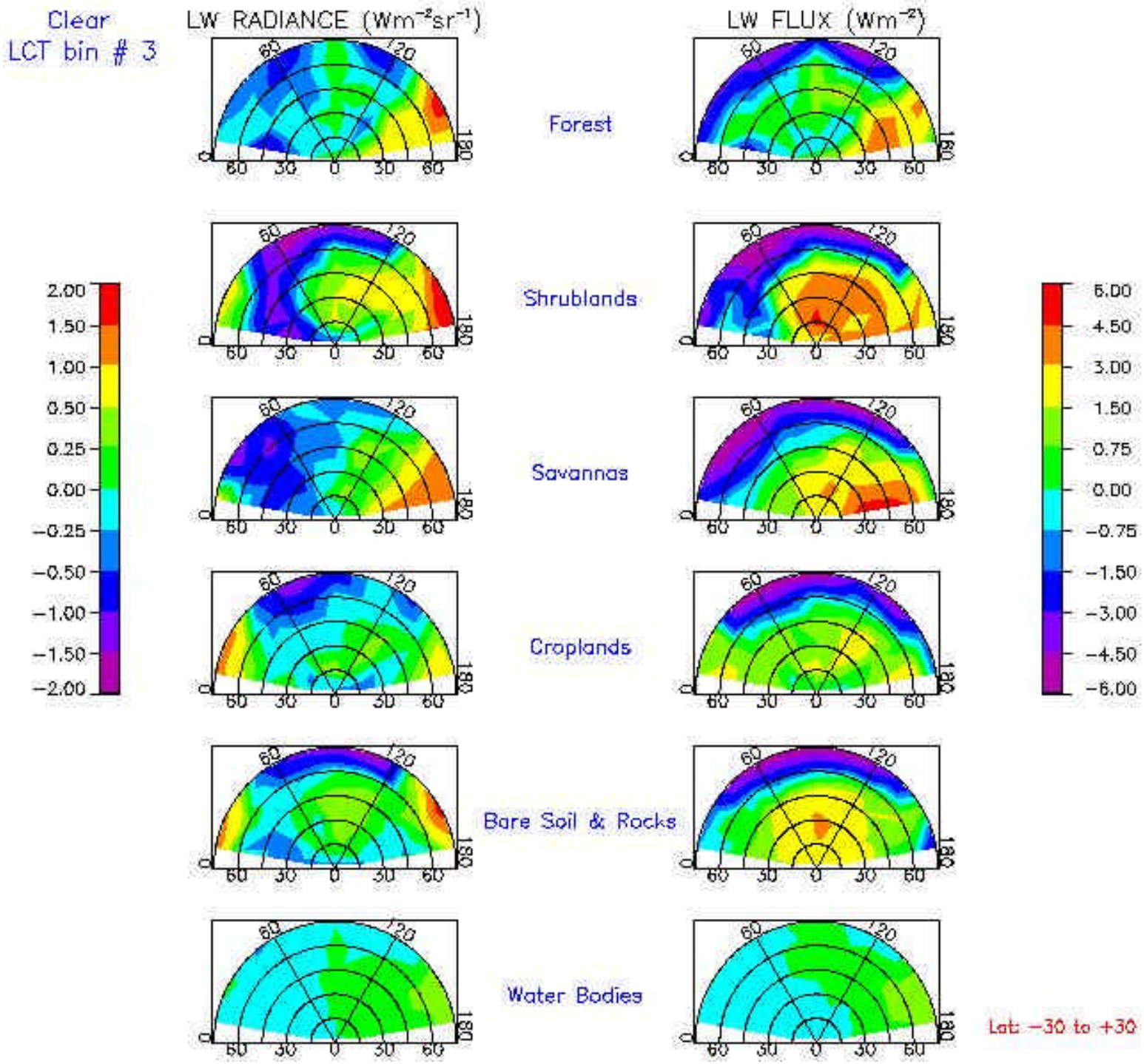

Clear
LCT bin # 4
LW RADIANCE (Wm⁻²sr⁻¹)
LW FLUX (Wm⁻²)
Forest
Shrublands
Savannas
Croplands
Bare Soil & Rocks
Water Bodies
2.00
1.50
1.00
0.50
0.25
0.00
−0.25
−0.50
−1.00
−1.50
−2.00
6.00
4.50
3.00
1.50
0.75
0.00
−0.75
−1.50
−3.00
−4.50
−6.00
Lat: −30 to +30

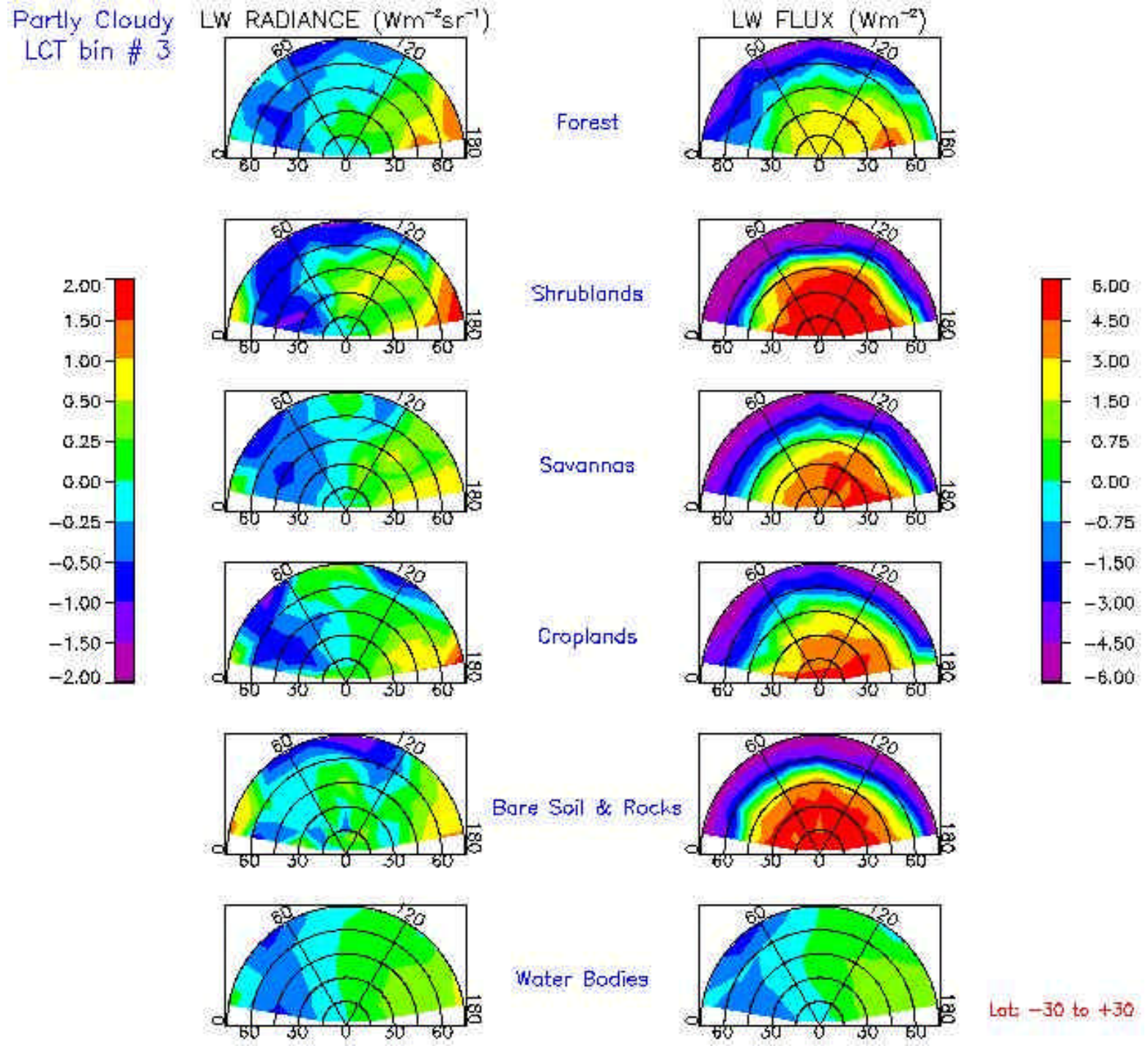

Clear
LCT bin # 2
LW RADIANCE (Wm⁻²sr⁻¹)
WN RADIANCE (Wm⁻²sr⁻¹)
Forest
Shrublands
Savannas
Croplands
Bare Soil & Rocks
Water Bodies
2.00
1.50
1.00
0.50
0.25
0.00
−0.25
−0.50
−1.00
−1.50
−2.00
1.00
0.75
0.50
0.25
0.12
0.00
−0.12
−0.25
−0.50
−0.75
−1.00
Lat: −30 to +30

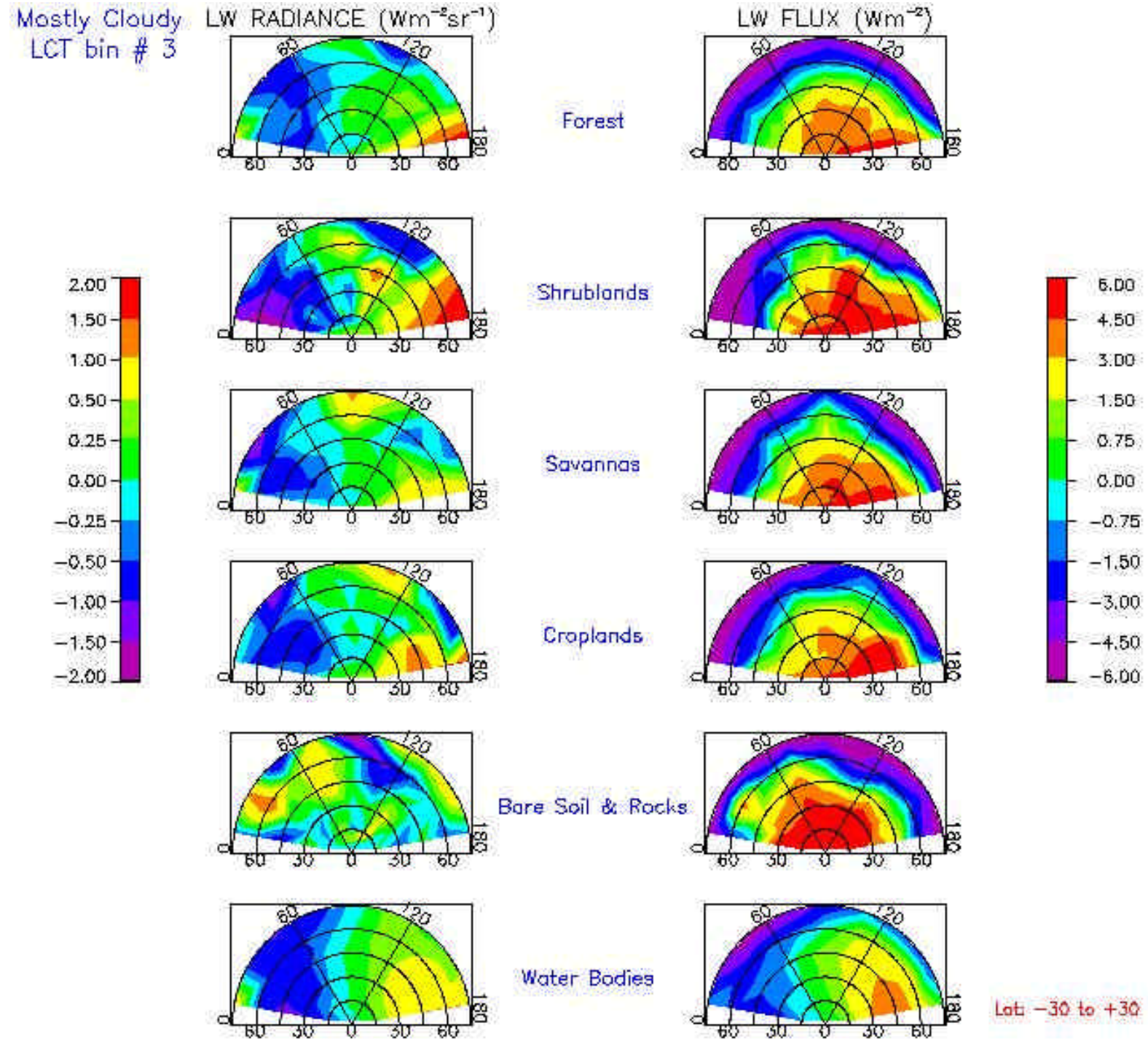

Clear
LCT bin # 2
Rel LW Temperature (K)
Rel WN Temperature (K)
Forest
Shrublands
Savannas
Croplands
Bare Soil & Rocks
Water Bodies
2.50
2.00
1.50
1.00
0.50
0.00
−0.50
−1.00
−1.50
−2.00
−2.50
Lat: −30 to +30

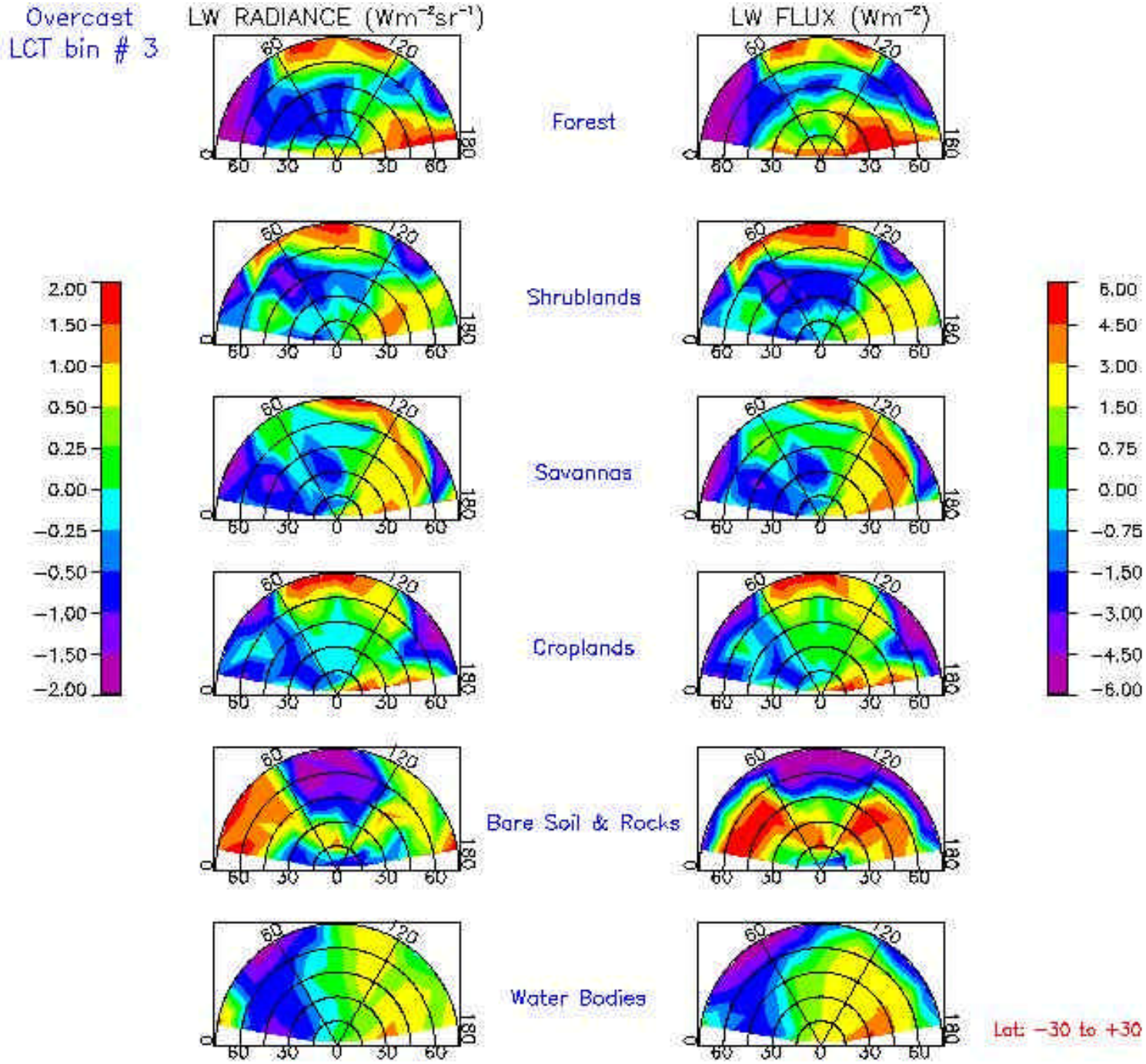

CLEAR
AZN SUMMED
LW (ABS) RAD in Wm⁻²sr⁻¹
LW (ABS) FLUX in Wm⁻²
PIX #
Forest
Shrublands
Savannas
Croplands
Baresoil–Rocks
Waterbodies
LCT BIN I
LCT BIN II
LCT BIN III
LCT BIN IV
VIEW ZENITH BINS
Lat: −30 to +30


CLEAR
AZN SUMMED
LW (REL) RAD in Wm⁻²sr⁻¹
LW (REL) FLUX in Wm⁻²
PIX #
Forest
Shrublands
Savannas
Croplands
Baresoil–Rocks
Waterbodies
8
0
−8
2.0×10⁴
1.0×10⁴
4×10⁴
1
2
3
4
5
LCT BIN I
LCT BIN II
LCT BIN III
LCT BIN IV
VIEW ZENITH BINS
Lat: −30 to +30


Clear
LCT bin # 3
LW RADIANCE (Wm⁻²sr⁻¹)
LW FLUX (Wm⁻²)
Forest
Shrublands
Savannas
Croplands
Bare Soil & Rocks
Water Bodies
2.00
1.50
1.00
0.50
0.25
0.00
−0.25
−0.50
−1.00
−1.50
−2.00
6.00
4.50
3.00
1.50
0.75
0.00
−0.75
−1.50
−3.00
−4.50
−6.00
Lat: −30 to +30


Partly Cloudy
LCT bin # 3
LW RADIANCE (Wm⁻²sr⁻¹)
LW FLUX (Wm⁻²)
Forest
Shrublands
Savannas
Croplands
Bare Soil & Rocks
Water Bodies
2.00
1.50
1.00
0.50
0.25
0.00
−0.25
−0.50
−1.00
−1.50
−2.00
6.00
4.50
3.00
1.50
0.75
0.00
−0.75
−1.50
−3.00
−4.50
−6.00
Lat: −30 to +30


Mostly Cloudy
LCT bin # 3
LW RADIANCE (Wm⁻²sr⁻¹)
LW FLUX (Wm⁻²)
Forest
Shrublands
Savannas
Croplands
Bare Soil & Rocks
Water Bodies
2.00
1.50
1.00
0.50
0.25
0.00
−0.25
−0.50
−1.00
−1.50
−2.00
6.00
4.50
3.00
1.50
0.75
0.00
−0.75
−1.50
−3.00
−4.50
−6.00
Lat: −30 to +30


Overcast
LCT bin # 3
LW RADIANCE (Wm⁻²sr⁻¹)
LW FLUX (Wm⁻²)
Forest
Shrublands
Savannas
Croplands
Bare Soil & Rocks
Water Bodies
2.00
1.50
1.00
0.50
0.25
0.00
−0.25
−0.50
−1.00
−1.50
−2.00
6.00
4.50
3.00
1.50
0.75
0.00
−0.75
−1.50
−3.00
−4.50
−6.00
Lat: −30 to +30

IGBP conclusions

- Clear ocean has no azimuthal signal
- Forested, Shrublands, and Savannas have a greater signal than croplands or bare soil
  - Up to 4° K window and 2° K longwave temperature difference between backward and forward scattering
- Partly and mostly cloudy scenes retain some of their azimuthal signature
- Window and longwave radiances have the same features